ARREGLOS INSTITUCIONALES PARA LA INTENSIFICACIÓN AGROECOLÓGICA

UNA MIRADA AL CASO BRASILEÑO DESDE LA AGROECOLOGÍA POLÍTICA

TESIS DOCTORAL

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Arreglos institucionales para la intensificación agroecológica: una mirada al caso brasileño desde la Agroecología Política

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Em uma época em que os que detêm o poder estão seduzidos pela mais estreita lógica ditada pelos interesses de grupos privilegiados, falar em desenvolvimento como reencontro com o gênio criativo de nossa cultura pode parecer fuga na utopia. Ora, o utópico muitas vezes é fruto da percepção de dimensões secretas da realidade, um afloramento de energias contidas que antecipa a ampliação do horizonte de possibilidades aberto a uma sociedade.

Celso Furtado (2002: *36-37)*

Por enquanto, o lugar –não importa sua dimensão– é a sede dessa resistência da sociedade civil, mas nada impede que aprendamos as formas de estender essa resistência às escalas mais altas. Para isso, é indispensável insistir na necessidade de conhecimento sistemático da realidade, mediante o tratamento analítico desse seu aspecto fundamental que é o território.

Milton Santos (2005*: 259-260)*

O grande desafio consiste na busca de outras maneiras de produzir, que não agridam e nem destruam a natureza, que valorizem o trabalho humano e contribuam efetivamente para o bem-estar das populações dos campos e das cidades. Os agricultores familiares, em sua grande diversidade, têm feito a sua parte.

Maria de Nazareth Baudel Wanderley (2009*: 44)*

Mediocrity cannot block superiority for long, especially not when the general public is interested and watching

Jan Douwe van der Ploeg (2009: 286)

Sumario

Resumen

Este trabajo analiza críticamente la internalización de la perspectiva agroecológica en las políticas de desarrollo rural en Brasil. El lazo de unión que articula el conjunto de artículos compilados en su composición está relacionado al papel del Estado en el apoyo a la creación y/o al fortalecimiento de arreglos institucionales de ámbito territorial que impulsan y sostienen trayectorias de desarrollo rural endógeno basadas en dinámicas de coproducción cultura-naturaleza. En términos analíticos, eses arreglos institucionales funcionan como dispositivos de acción colectiva que apoyan el despliegue de trayectorias de intensificación productiva de los agroecosistemas basadas en el perfeccionamiento sistemático del proceso de trabajo agrícola y en la ampliación cuantitativa y cualitativa de la base de recursos auto controlada por las familias agricultoras y sus comunidades. En ese sentido, contrastan con los arreglos institucionales moldeados desde la perspectiva de la modernización agrícola, cuya lógica de intensificación productiva genera dependencia estructural de la agricultura a los mercados de factores de producción. El primer artículo sitúa la emergencia de la Agroecología como una teoría crítica en el actual contexto histórico de crisis socioecológica de alcance planetario. El argumento central del texto apunta hacia la necesidad de cambios en los arreglos institucionales que regulan el metabolismo de los sistemas agroalimentarios con el fin de que el enfoque agroecológico sea aplicado en escalas superiores. Entre otras características destacadas, eses cambios institucionales deben favorecer procesos de desmercantilización de los sistemas agroalimentarios por medio de la restauración y multiplicación de flujos económico-ecológicos regulados por relaciones de reciprocidad. El segundo artículo presenta un panorama general del proceso de institucionalización del abordaje agroecológica en Brasil, destacando algunos de los obstáculos prácticos, teóricos y político-ideológicos para la superación del paradigma de la modernización en las instituciones del Estado. El artículo siguiente analiza la contribución de las nuevas generaciones de políticas públicas para la formación de arreglos institucionales en el territorio de la Borborema, región localizada en el semiárido brasileño, donde hace más de 20 años viene se desarrollando una vigorosa red socio-técnica de Agroecología liderada por organizaciones de agricultura familiar. El cuarto artículo presenta una metodología para el análisis de agroecossistemas concebida para dar visibilidad y valorar los flujos metabólicos que integran las estrategias de reproducción técnico-económica de la agricultura familiar. Al situar los agroecosistemas en el tiempo y en el espacio, la metodología propuesta permite caracterizar simultáneamente sus trayectorias evolutivas y sus vínculos económico-ecológicos en los ambientes institucionales de su entorno. Por medio de esa doble mirada se hace posible identificar movimientos de transformación en la estructura y funcionamiento de los agroecosistemas así como los resultantes grados de mercantilización del proceso de trabajo agrícola. Ese abordaje analítico permite entender los agroecosistemas como expresiones sociomateriales de las estrategias activamente construidas por las familias agricultoras y sus comunidades frente a las oportunidades y restricciones que se enfrentan para reproducir sus medios y modos de vida. Basado en la aplicación de esa metodología, el estudio presentado en el quinto y último texto aborda la contribución de los nuevos arreglos institucionales en el territorio de Borborema en las dinámicas de intensificación los agroecosistemas, demostrando el rol de la perspectiva agroecológica en la combinación sinérgica entre los recursos territoriales endógenos (materiales y inmateriales) y los recursos públicos redistribuídos por el Estado.

Introducción

En artículo publicado en el periódico mexicano “La Jornada”, durante la celebración de la Conferencia de las Naciones Unidas sobre el Cambio Climático (COP 21), en diciembre de 2015, Victor Manuel Toledo llamó la atención para el hecho de que posiblemente aquel sería el cónclave mundial más importante de la historia (Toledo 2015). “Ya no se trata de dirimir conflictos entre países, bloques o incluso entre regiones del mundo, sino del destino de todos y de su entorno planetário”. En analogía con el síntoma de desequilibrio sistémico en el organismo humano, él decía que el planeta tiene fiebre. “Un estado patológico de escala global, provocado por el próprio ser humano convertido ya en una nueva fuerza geológica” (idem).

En la misma línea de raciocinio, y haciendo una referencia a las elaboraciones de Prigogine (1996) sobre la crisis estructural de sistemas distantes del equilibrio, Wallerstein (2005) afirma que vivimos en un tiempo de bifurcación histórica. Se trata de la crisis estructural del sistema-mundo, un sistema que emergió hace unos cinco siglos en la era de expansionismo europeo (Braudel 1995), cuando la rápida ampliación de las fronteras de apropiación ecológica y de explotación social proporcionó niveles sin precedentes de acumulación de capital y de poder, pavimentando el camino para el desarrollo de las bases institucionales del capitalismo.

Una de las principales características de la crisis de un sistema es el surgimiento de fluctuaciones caóticas en su funcionamiento dinámico. El notable aumento en la inestabilidad global a partir de 2008, con la intensificación de las turbulencias económicas, políticas, sociales, ambientales y climáticas es presentado como la evidencia de una crisis terminal del sistema-mundo. Aunque el actual momento histórico permanece siendo descrito y analizado como el resultado de la convergencia de múltiples crisis (George 2010), se ha vuelto cada vez más evidente que vivimos una crisis singular, de carácter estructural, que expone los límites de la civilización moderna (Garrido Peña et al. 2007; Toledo 2012).

Al describir y analizar los abruptos cambios ambientales a escala planetaria en el siglo XX, principalmente después de la segunda guerra mundial, McNeill (2001:4) concluye que la humanidad está involucrada en un "gigantesco experimento sin control". Pocos años después del lanzamiento de este amplio estudio sobre la historia ambiental del siglo pasado, Rockström et al. (2009) demostraron cómo las presiones antropogénicas sobre el sistema terrestre sobrepasaron algunas fronteras de seguridad ligadas a la capacidad de restablecimiento de

dinámicas ecológicas a escala planetaria. Al analizar el prisma económico, Piketty (2014) mostró cómo la evolución reciente del sistema de gobernanza económica global ha generado niveles de concentración de renta y de desigualdad social equiparables al del siglo XIX, con claras tendencias de empeoramiento.

Por lo tanto, los sintomas de la actual crisis del capitalismo sugieren que estamos asistiendo un fenómeno inédito que no será solucionado con el mismo patrón de respuesta adoptado en las crisis cíclicas del pasado, es decir,

> "by putting nature to work in powerful new ways" … a través de "new technologies and new organizations of power and production" (Moore 2015: 1).

La reforma neoliberal promovida a partir de la década de 1970 corresponde solamente al más reciente ejemplo de ese patrón de reajuste estructural del sistema frente a las crisis sistémicas del capitalismo. Sin embargo, desde entonces, los intentos de superación de la crisis a través de la ampliación de las "fronteras de apropiación de la naturaleza" (incluso la naturaleza humana) vienen fallando.

> "This indicates we may be experiencing not merely a transition from one phase of capitalism to another, but something more epochal: the breakdown of the strategies and relations that have sustained capital accumulation over the past five centuries" (idem).

La magnitud de las transformaciones necesarias en ese momento de "bifurcación histórica" posiblemente sólo encuentre dos precedentes en el transcurso de los 200 mil años comprendidos por la presencia humana en el planeta: 1) la revolución neolítica, con el advenimiento de la agricultura, hace unos diez mil años; 2) la revolución industrial, proceso iniciado hace unos 300 años, cuyo despliegue nos condujo al actual estado de crisis multifacetada a escala global. Estos dos "momentos revolucionarios" impulsaron cambios a gran escala y de largo alcance en las formas como la humanidad se integra al conjunto de la Biosfera, así como en las configuraciones societarias correspondientes.

Todo indica que el enfrentamiento de las causas y efectos de los ya inexorables cambios climáticos, así como de los demás síntomas de la crisis global que corroe las bases de las sociedades modernas requiera transformaciones socioecológicas de igual radicalidad. Sin embargo, a diferencia de los procesos anteriores, nacidos localmente y diseminados

globalmente, los cambios actualmente necesarios, en la llamada "era de la globalización" (Giddens 2000) y del “Império” (Hardt e Negri 2000), cobran el concurso de transformaciones en las estructuras de gobernanza del metabolismo social en diferentes escalas, desde el ámbito local / territorial hasta el ámbito global.

Este trabajo retoma y profundiza las reflexiones presentadas en la disertación de maestría (Petersen 2011), cuando sostuve la idea de que la salida del actual impasse civilizatorio no ocurrirá como una revolución centralmente planificada, sino como un proceso multiescalar de "metamorfosis" en los arreglos institucionales que regulan los patrones de producción, distribución y consumo de riquezas sociales. La analogía entre la superación del sistema-mundo en crisis y el proceso biológico de la metamorfosis, propuesta por Edgar Morin (2007; 2010)[i], resalta dos aspectos interdependientes, siendo uno de orden intelectual (el plan de la reflexión) y otro de orden político (el plan de la acción colectiva).

Desde el punto de vista político, la noción de metamorfosis abre el camino para la superación de un antiguo embate en el seno de las fuerzas progresistas que puede ser sintetizado con el título del libro de Rosa Luxemburgo lanzado aún a principios del siglo XX: "Reforma o Revolución?" (Luxemburgo [1900] 2010). Al igual que la transformación de la oruga en mariposa, la metamorfosis combina el gradualismo de los cambios dentro del sistema, como abogan los reformistas, con la inmediata ruptura con el orden sistémico, como defienden los revolucionarios.

Desde el punto de vista intelectual, implica reconocer la inexistencia de un centro gravitacional de las fuerzas de transformación. Ellas están dispersas en el mundo y se organizan en forma de redes estructuradas en diferentes escalas, desde los más recónditos rincones hasta las incipientes iniciativas de articulación de una sociedad civil global unificada bajo el lema "Otro Mundo es Posible". Esto significa que los procesos transformativos no serán orientados por una teoría universal puesta en práctica por fuerzas vanguardistas. Significa también que estos procesos ya están en curso y se expresan en una miríada de prácticas sociales que inspiran caminos para la reconstrucción del sistema según otros fundamentos económicos y valores societales.

En ese sentido, la proposición de la metamorfosis se alinea a la tesis defendida por Holloway (2013) vinculada a la necesidad de fisurar el sistema hegemónico a partir de experiencias sociales concretas por medio de las cuales se construyen crecientes grados de autonomía en relación a los modos de producción comandados por la lógica del capital. Para el autor, "la

única manera de pensar en cambiar el mundo radicalmente es con una multiplicidad de movimientos intersticiales fluyendo a partir del particular" (idem:15).

Sin embargo, la valorización de esas experiencias desarrolladas en las fisuras del sistema como fuerzas impulsoras de la metamorfosis no ocurrirá con el empleo de una teoría general producida por el propio sistema. El patrón hegemónico de producción de conocimiento, institucionalmente impuesto como el único legítimo, no puede ser comprendido de forma disociada de los modos dominantes de producción y de distribución de riqueza social, o sea, de las formas como la humanidad se relaciona con el resto de la naturaleza.[ii]

Como defiende Capra (2005), la crisis del sistema-mundo moderno es, antes de todo, una "crisis de percepción" o, como prefieren, Toledo e Barrera-Bassols (2015), una "crisis de concepción del mundo". Por esta razón, no puede ser enfrentada a partir de estrategias de acción concebidas a partir de la escisión ontológica entre el mundo social y el mundo natural. Esta es también la razón por la cual Moore (2015) defiende la idea de que el capitalismo no debe interpretarse como un "sistema económico" ni como un "sistema social", sino como una "forma de organizar la naturaleza".

El reconocimiento, la traducción y la valorización de las experiencias contrahegemónicas exigen, por lo tanto, la superación del monopolio de la ciencia moderna y la instauración de una "ecología de saberes", es decir, un enfoque de construcción de conocimientos que acoja la "diversidad epistemológica del mundo" sin disolver las identidades particulares (Sousa Santos 2008).[iii] La noción de ecología de saberes se fundamenta en tres constataciones:

> “En primer lugar, la experiencia social en todo el mundo es mucho más amplia y variada de lo que la tradición científica o filosófica occidental conoce y considera importante. En segundo lugar, esta riqueza social se está desperdiciando. Es desde este desperdicio que se nutren las ideas que proclaman que no hay alternativa, que la historia llegó a su fin y otras semejantes. En tercer lugar, para combatir el desperdicio de la experiencia, para hacer visibles las iniciativas y los movimientos alternativos y para darles credibilidad, de poco sirve recurrir a la ciência social tal como la conocemos. A fin de cuentas, esta ciencia es responsable de esconder o desacreditar las alternativas. Para combatir el desperdicio de la experiencia social, no basta proponer otro tipo

> de ciencia social. Más que esto, es necesario proponer un modo diferente de racionalidad (idem: 94).

Por lo tanto, en lugar de los caminos hacia el futuro predeterminados por la ciencia, la metamorfosis deja abierta la Historia. Como dice Morin (2011:31),

> "la historia no avanza de modo frontal, sino por desvíos que se fortalecen y se transforman en tendencias".

Pero eso no significa que el futuro no pueda ser preparado (Prigogine 1994). Essa é uma tarefa que cabe à política (Weber 1998). No entanto, a política concebida a partir da racionalidade do capital

> “se comporta como si no hubiera tiempo... del no recocimiento político de la entropía, del olvido de la misma surge la ilusión de un tiempo eterno” (Garrido Peña 1993: 11).

Aunque estea ampliamente establecido que la "cuestión ecológica" sea un problema de naturaleza política, es mucho menos evidente que la "cuestión política" sea un problema de naturaleza ecológica (Pádua 1989). Las instituciones prevalecientes en las sociedades contemporáneas, incluyendo el Estado moderno y los mercados formadores de precios, son emergencias históricas que encuentran sus raíces en las formas como el ser humano se integra al resto de la naturaleza. La inauguración de la era moderna, con revolución industrial, ha traído dos cambios culturales interdependientes que influenciaron decisivamente la conformación de los arreglos institucionales posteriores: a) La emergencia del mito del crecimiento ilimitado, una ilusión metafísica alimentada por el desarrollo de las tecnologías mecánicas y la colonización de territorios en el nuevo mundo, ampliando abruptamente las fronteras de apropiación ecológica; b) la valorización del espacio privado y de la libre iniciativa, siendo el mercado ungido como el principal motor y cemento de la vida social.

Gracias a los avances en el enfoque sistémico aplicado por la ecología, se ha podido examinar críticamente un conjunto de cuestiones relacionadas con la integración de la humanidad en el resto de la naturaleza. Ante la creciente percepción de las raíces ambientales de la crisis civilizacional contemporánea, los movimientos ecologistas emergieron a mediados del siglo 20 al asociar la crítica a los modelos de desarrollo dominantes al conocimiento científico aportado por la Ecología (McCormick 1992). A través de un proceso recursivo, ese mismo movimiento político retornó a la ciencia, cobrando la elaboración de un nuevo cuerpo de conocimientos a ser desarrollado en una doble dirección: 1) como un campo disciplinario que se ocupa del

diseño de arreglos institucionales y normas que regulan el comportamiento colectivo, contribuyendo a orientar las transiciones societarias hacia la sostenibilidad ecológica y la justicia social; 2) Como una ideología que entra en confrontación con el paradigma hegemónico de desarrollo, que tiene su fundamento en la idea de crecimiento ilimitado. A través de ese proceso recursivo (eminentemente ecológico) se crearon las condiciones para el surgimiento de la Ecología Política.[iv]

Como aclara Martínez-Alier (2015: 71)

> "el vínculo entre la sustentabilidad y la ecología política es claro ya que, por un lado, permite desenmascarar los actores y las relaciones de poder presentes que moldean la economía y la política, al tiempo que, por el otro, reconoce a los movimientos de justicia ambiental como actores clave para la acción colectiva en la defensa de los territorios y de sus poblaciones y el planteamiento y construcción de procesos hacia otras territorialidades ambientalmente viables y socialmente más justas".

Para Toledo (2011), la ecología política también puede ser comprendida como

> "una nueva filosofía que respalda processos subterráneos, rizomáticos y silenciosos que avanzan generando "espacios de autonomia" en relación al ordenamiento del trabajo impuesto por las reglas de los mercados por medio del desarrollo de economías fuertemente basadas en mecanismos de cooperación social y de "reciprocidad con la naturaleza".

Resistencia, autonomía y sostenibilidad son conceptos clave que se moldean mutuamente en la definición de esas experiencias sociales emergentes construidas a partir del "lugar de trabajo" (Ploeg 2007). Se trata de un patrón de resistencia activamente construido con base en la alteración de la realidad sociomaterial del proceso de trabajo, buscando exactamente la construcción de mayores niveles de autonomía en relación a diferentes formas de opresión contra las prácticas de reproducción socioecológica.

La Ecología Política reconoce estas experiencias sociales emergentes y las concede un estatuto teórico de gran relevancia como expresiones empíricas de alternativas a la crisis de civilización vigente. En los términos aquí defendidos, ellas corresponden a fuerzas materiales de la metamorfosis. Como iniciativas descentralizadas de contra tendencia al movimiento agresivo y

expansivo do capital, contradicen de variadas formas los procesos de homogeneización de los estándares de organización de la vida social y económica moldeados por el individualismo y el predominio de los valores de cambio sobre los valores de uso. Por la lente de la Ecología Política, la diversidad de la experiencia social no es interpretada como la reminiscencia de un pasado condenado a desaparecer, sino como embriones de un futuro en gestación. Un futuro coherente con la historia de la Biosfera, una historia de desarrollos desiguales.

La ecología política y las nuevas lenguajes de valoración

La oficialización por las Organizaciones de las Naciones Unidas de la "Agenda 2030 - Transformando Nuestro Mundo" puso en el orden del día de la comunidad internacional un conjunto global de Objetivos del Desarrollo Sostenible (ODS) (UN 2015). Pese a la debilidad política de ese documento como instrumento vinculante de las políticas nacionales, él posee la virtud pedagógica de lanzar luces sobre un amplio abanico de desafíos a ser abordados de forma combinada en el curso de los próximos años.

Posiblemente el mayor de los desafíos a ser enfrentados para el alcance combinado del rol de 17 ODS (y sus 169 metas asociadas) sea la superación de las irreconciliables contradicciones entre los acuerdos de gobernanza global en las áreas de medio ambiente y de economía y comercio. La superación de este desafío de primer orden no resultará de la coexistencia de nuevas iniciativas de carácter ambiental con las viejas acciones dirigidas al desarrollo económico, como ocurre desde la Conferencia de las Naciones Unidas sobre el Medio Ambiente Humano, celebrada en 1972, en Estocolmo (Veiga 2013).

Ante esta inercia institucional, el desarrollo sigue siendo concebido, promovido y legitimado como el resultado automático del crecimiento económico, un proceso social aferido por las variaciones en el Producto Interno Bruto (PIB). Sin embargo, esta medida de desempeño económico no discierne si los bienes o servicios producidos por las naciones son beneficiosos o maléficos para sus perspectivas de bienestar y sostenibilidad. Tampoco contabiliza los intercambios económicos no mercantilizados y la degradación de los bienes naturales empleados en el proceso económico. Por lo tanto, además de despreciar la importancia del trabajo reproductivo y los intercambios económicos basados en la reciprocidad, el PIB es un indicador incapaz de captar la distinción entre los procesos productivos y los destructivos.

Poco después de la Conferencia de Estocolmo, Celso Furtado (1974) llamó la atención sobre el hecho de que la idea de desarrollo económico es un mito. Motivado por la reciente publicación del estudio, "Los límites del crecimiento" (Meadows et al. 1973) él se preguntaba:

> “Como negar que essa ideia tem sido de grande utilidade para mobilizar os povos da periferia e levá-los a aceitar enormes sacrifícios, para legitimar a destruição de formas de vida arcaicas, para explicar e fazer compreender a necessidade de destruir o meio físico, para justificar formas de dependência que reforçam o caráter predatório do sistema produtivo?” (Furtado 1974: 75).

En la introducción de su obra, Furtado analizaba la importancia del mito del desarrollo económico en la conformación, en un plano intuitivo, de la visión del proceso social. El mito

> “opera como um farol que ilumina o campo de percepção do cientista social, permitindo-lhe uma visão clara de certos problemas e nada de outros” (idem: 7).

Al proyectar luces sobre las relaciones entre las desigualdades de poder y la degradación ecológica, la Ecología Política contribuye a iluminar parcelas de la realidad ocultadas por el paradigma económico dominante, un cuerpo de conocimientos que representa la organización de la vida social y su articulación orgánica en el mundo natural con base en supuestos mecanicistas referenciados en una alegada neutralidad política de los procesos económicos y en la creencia de la ilimitada capacidad de la naturaleza de suministrar recursos y de absorber residuos de los procesos productivos. En ese sentido, la Ecología Política se presenta como un referencial de suma relevancia para la superación de la "crisis de percepción" apuntada por Capra.

De acuerdo con Martínez-Alier (2007), el poder es abordado en la Ecología Política por dos perspectivas complementarias: la primera, más explícita, se refiere a la capacidad de imposición de decisiones de unos sobre otros; la segunda, más sutil, resalta la imposición del “lenguaje de valoración”. A pesar de más insidiosa, esta segunda perspectiva es central en la legitimación social del sistema de poder que gobierna los procesos económicos en la sociedad.

Como aclara Moore (2015), las civilizaciones se organizan a partir de sus prioridades, es decir, decidiendo qué cosas y qué relaciones son valiosas. Según su interpretación, el capitalismo instituyó un sistema de valoración peculiar y sin precedentes. En las nuevas configuraciones societarias formadas a partir de la emergencia histórica de este nuevo "sistema de organización de la naturaleza", el valor pasó a determinarse por la productividad del trabajo en la producción de mercancías, contrastando con los lenguajes de valoración anteriores, siempre

ligadas a referenciales más amplios relacionados a la atención de necesidades efectivas del ser humano, ya sean materiales o inmateriales.

> "Never before had any civilization negotiated the transition from land productivity to labor productivity as the metric of wealth… The implication is explosive: the law of value represents a determination of socially necessary labor-time, which occurs simultaneously through organizational and technical innovation and through strategies of appropriating the unpaid work/energy of 'women, nature, and colonies'…" De esa forma, "the history of capitalism flows through islands of commodity production, developing within oceans of unpaid work/energy" (idem: 51-54).

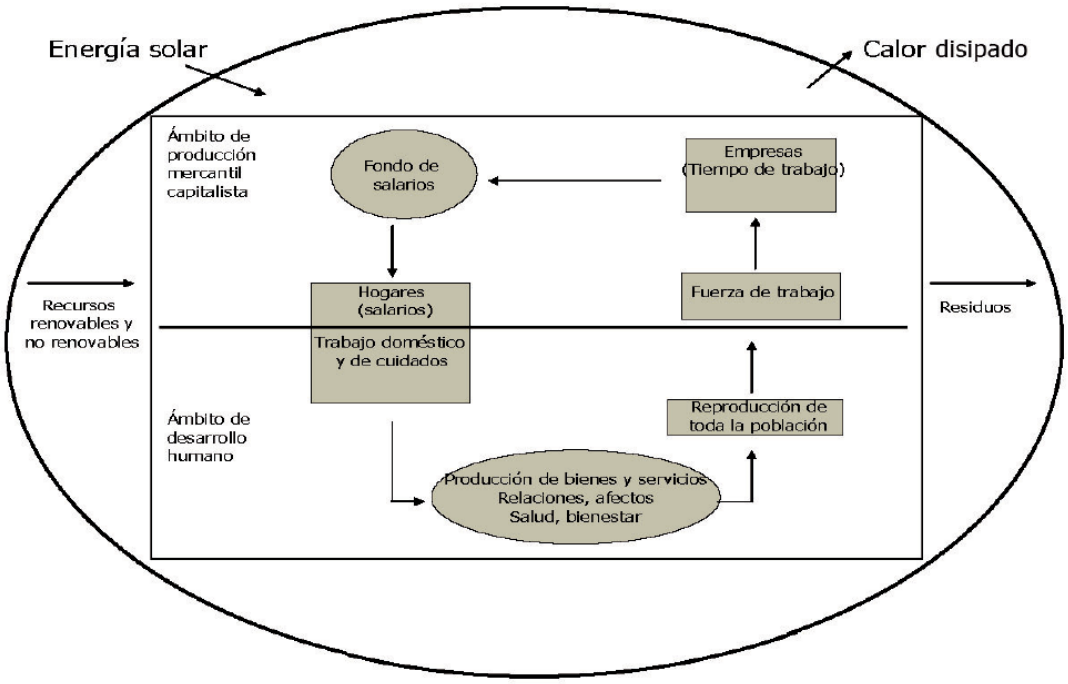
Esa significativa metáfora de islas de mercancías en oceanos de trabajo/energía no valorado es representada en el diagrama reproducido en la Figura 1. El círculo externo representa la naturaleza, donde el sistema social extrae recursos (renobables y no renobables) y hacia donde devuelve residuos. La línea horizontal representa la frontera simbólica entre las esferas de la producción económica y de la reproducción social establecida por el sistema institucional dominante. Segundo Carrasco (2011: 209),

> "los distintos trabajos – trabajos desarrollados bajo distintas relaciones sociales – están intimamente relacionados siendo dependientes unos de los otros; es decir, existe una relación dinâmica entre el procesos de producción y reproducción de mercancías y el proceso de reproducción de la población y, en particular, de la fuerza de trabajo. Y, por otra, la frontera entre ambos espacios es porosa y cambiante, dependiendo del desarrollo tecnológico y de los niveles de renta. De hecho, hay determinadas producciones de bienes que según la situación sociohistórica de la sociedad – o del hogar – han pasado de un ámbito a outro".

Al proporcionar la visualización del encadenamiento de los flujos de trabajo desde una perspectiva sustantiva del proceso económico (Polanyi 2012b)[v], este esquema contribuye a evidenciar el vínculo indisociable entre la explotación del trabajo humano mercantilizado (parte superior del rectángulo) y la apropiación del trabajo/energía no pagado de la naturaleza

(parte externa al rectángulo), incluyendo allí el trabajo humano, principalmente el de las mujeres (parte inferior del rectángulo).

Figura 1. El circuito del trabajo (Carrasco 2011)



Sobre la base de un sistema de valoración que restringe el valor al precio se erigió y se legitimó el modo de producción cuya fuerza motora es la acumulación desenfrenada a través de la explotación del trabajo pagado y de la apropiación del trabajo no pagado en los circuitos de reproducción del capital. Es exactamente ese sistema de valoración que no contabiliza parte importante del trabajo humano invertido en los procesos de reproducción social y desconsidera integralmente las dinámicas de reproducción ecológica el responsable por la consolidación de instituciones sociales que están en la raíz de la crisis civilizatoria contemporánea.

La gran transformación metabólica

Aunque las raíces profundas del moderno sistema-mundo se sitúan en el siglo XVI (Wallerstein 1974), fue a partir del siglo XVIII que se procesó la "gran transformación" descrita y analizada por Polanyi (2001).

> “The crucial step was that labor and land were made into commodities; that is, they are treated as if they had been produced for sale. …. Yet no more thoroughly effective fiction was ever devised” (Polanyi 1977: 10). Within a generation – say 1815 to 1845 - … the price-maked market, … showed its staggering capacity for organizing human beings as they were mere chunks of raw material and combining them, togheter with the surface of mother earth, which could now be freely marked, into industrial units under the command of private persons mainly engaged in buying and selling for profit. Within an extremelly brief period, the commodity fiction, as applies to labor and land, transform the very substance of human society” (ídem: 9).

Esta ruptura (“violent break” como ha sido caracterizado por Polanyi) con las sociedades premodernas surge como una verdadera inversión:

> "Instead of economy being embedded in social relations, social relations are embedded in the economic system” (Polanyi 2001: 60).

Ese proceso de desarraigo en el interior de la esfera social no sería posible si no hubiera un correspondiente desarraigo de la economía en relación a las dinámicas locales de funcionamiento de los ecosistemas. Desde el punto de vista material, ese cambio abrupto en la organización social del trabajo se ha hecho posible con el empleo generalizado de combustibles fósiles.

> “El capitalismo fosilista surgió como consecuencia de un uso intensivo de la energía fósil, en primer lugar, del carbón, y de un desarrollo técnico que permitió explotar al máximo esta nueva energía. Esto posibilitó, y a la vez requirió, una expansión de las lógicas de funcionamiento capitalistas a nivel planetario, con la interconexión de casi todos los territorios dentro del sistema-mundo” (Fernández Durán e González Reyes 2014: 241).

La progresiva sustitución de la energía solar captada por la fotosíntesis por la “fotosíntesis embotellada hace millones de años” (Martínez-Alier 2016) transformó radicalmente el papel de las actividades agrarias en el metabolismo social ya que la biomasa dejó de ejercer el papel

central como fuente de energía que hace funcionar la sociedad (González de Molina e Toledo 2011). Seguiendo la caracterización hecha por Polanyi (2001), ese período histórico podria ser denominado como la "gran transformación metabólica" ya que

> “el proceso de la apropriación ha pasado a ocupar un lugar subsidiário, valorado más como proveedor de materiales y funciones ambientales que de energía. Son los procesos de transformación …, circulación, consumo y excreción los que han adquirido el protagonismo que antes correspondía a la apropriación” (González de Molina e Toledo 2011: 243).

Considerando el hecho de que la energía es la fuerza elemental y el medio por el cual la cultura humana es moldeada (White 2005) por medio de innovaciones exosomáticas (Nicholas Georgescu-Roegen 1976) y que

> “la cantidad y cualidades de la energía disponible han marcado un contexto básico que ha configurado los límites en los que las sociedades humanas han evolucionado” (Fernández Durán e González Reyes 2014: 22),

el cambio en el régimen energético que ha posibilitado la Revolución Industrial fue responsable por formas inéditas de división social del trabajo.

> “El uso de nuevas fuentes de energía no solo potenció la capacidad del productor para extraer un mayor flujo de bienes de la naturaleza, también amplificó la escala de la producción, especializó a los productores y aumentó su dependencia respecto de insumos externos, es decir, de aquellos no obtenidos de su entorno inmediato” (González de Molina e Toledo 2011: 137-8).

La mayor densidad calorífica de esas nuevas fuentes energéticas asociada al control centralizado de las mismas crearon las condiciones materiales necesarias para que los mercados hayan asumido un creciente poder de mando y control sobre los flujos del metabolismo social. Como "una relación social que asigna los flujos de energía y materiales" (ídem: 249), el mercado fue el vector determinante del cambio metabólico que permitió que los métodos capitalistas para la satisfacción de las "necesidades cotidianas", restringidos al mundo occidental hasta mediados del siglo XIX, hagan se tornado tan predominantes a punto de caracterizar una nueva era de la historia económica de la humanidad (Weber 2003) .

La creciente penetración de la "lógica del mercado" en la organización de la vida social en el “El Largo Siglo XX” (Arrighi 2006) llevó a la conformación de un sistema institucional altamente jerarquizado y desterritorializado responsable por la gobernanza de los flujos económico-financieros en escala global. Este nuevo y poderoso modo de ordenamiento es responsable por la reorganización de grandes dominios del mundo social y del mundo natural, sujetándolos a nuevas formas de control centralizado y de apropiación masiva (Ploeg 2008). Dada su característica de "conquista, mando y control a distancia" por medio de normas, parámetros y procedimientos de regulación del metabolismo social, esta es la razón por la cual esta superestructura global de gobernanza es definida por medio de la noción de "Imperio" (Hardt e Negri 2000).

Esta actual conformación del sistema-mundo en la forma de un régimen imperial debe ser comprendido, por lo tanto, como el resultado de un proceso coevolutivo entre sistemas técnicos y sistemas institucionales que tuvo su origen en el siglo XVI. Este sistema funciona como una estructura coercitiva compuesta por esquemas reguladores de naturaleza política y económica asociados a nuevas tecnologías para la intervención en el mundo natural. Siguiendo la proposición de Moore (2015), el Imperio debe ser comprendido como la actual forma de "organización de la naturaleza" (humana y extra-humana), una forma que permitió una concentración de poder sin precedentes en la historia.

La especificidad histórica del Imperio reside en la combinación contradictoria, pero sistemática, de dos principios orientadores: el mercado global y el sistema de línea de montaje (Ploeg 2009).

> “With the dazzling expansión of the social, spatial (and even temporal) divisions of labor and the subsequent expansión of markets, control becomes absolutely crucial. Therefore, the assembly-line principle (effectuated through control at a distance) is reconstituted and combined with the marked. … Citizens, who are assumed to move ‘freely’ in the newly created ‘free markets’, are subjected to asphyxiatying protocols and procedures for planning and control that tend to exclude agency and responsability. They are facing ‘markets’ that, in practice, turn out to be coercitive structures that only allow for specific routines” (ídem: 255-256).

La ya referida crisis estructural del moderno sistema-mundo está directamente asociada a ese patrón técnico-institucional de gobernanza global del metabolismo socioecológico (Fischer-Kowalski et al. 2014). Dos factores principales explican la gran vulnerabilidad del sistema en su actual etapa evolutiva.

Por un lado, la enorme concentración de poder político-económico en un número cada vez menor de *players* en los mercados genera una menor resiliencia institucional para lidiar con riesgos e incertidumbres. Aunque los mercados sean una institución notable para la integración social (Polanyi), para que sus funciones positivas se desarrollen en beneficio de las sociedades, se hace necesario un ambiente institucional de "democracia económica" (Dowbor 2008). Sin embargo, en la actual fase del capitalismo, las regulaciones que protegen los intereses sociales (incluida la conservación de la naturaleza) son eliminadas; las fronteras económicas son removidas de forma que los intereses corporativos se pongan por encima de los Estados; el derecho de los consumidores a la información es denegado; las tecnologías son patentadas y monopolizadas; fusiones, adquisiciones y alianzas estratégicas entre corporaciones son empleadas minando la capacidad de los mercados de auto-organizarse (Korten 2014).

Por otro lado, esta estructura centralizada de poder hace que el metabolismo socioecológico funcione a partir de flujos lineales de materia y energía, como si la naturaleza fuera una fuente interminable de recursos y un sumidero infinito de residuos. Las instituciones diseñadas a partir de esta “ilusión metafísica” (Garrido Peña et al. 2007) promueven procesos económicos altamente entrópicos (Georgescu-Roegen 1971) que ya comprometen la manutención de mecanismos de homeostasis planetarios, en particular aquellos relacionados con el equilibrio del clima, con la conservación de la biodiversidad y los ciclos de nutrientes (Rockström et al. 2009).

La crisis sistémica estructural generada por el agotamiento de los recursos naturales y por el cambio en el patrón de funcionamiento de la biosfera expone "la segunda contradicción del capitalismo", tal como definida por O’Connor (1991).[vi] Esta es la razón por la cual algunos autores da Ecología Política ya prefieren denominar la llamada "era del antropoceno" (Steffen et al. 2007) como “era del capitaloceno” (Moore 2016).

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Notas de la introducción

[i] "La Historia llega a su agotamiento, no porque no haya nada más que inventar, como piensa Fukuyama [1992], sino porque todo debe ser reinventado para salvar la humanidad del riesgo en el aniquilamiento... Porque la Historia, nacida muy recientemente en la evolución humana, puede desaparecer sin que la evolución cese [...] Desafortunadamente, es posible salir de la Historia por abajo, por la regresión generalizada... Salir de la Historia por encima sería pasar por una metamorfosis... Cuando un sistema es incapaz de tratar sus problemas vitales, se degrada o se desintegra o entonces es capaz de suscitar um metasistema para lidiar con sus problemas: él se metamorfosea" (Morin 2007: 179 e 181).

[ii] "The production of knowledge itself is constitutive of capitalist world-praxis and its trinity – abstract social labor, abstract social nature, primitive accumulation. Without this, the "triple helix" of commodification (labor, land, and the commodities produced) could not develop over large-space and long-time" (Moore 2015: 195).

[iii] A ecologia de saberes assenta-se em dois pressupostos: "1) não há epistemologias neutras e as que clamam sê-lo são as menos neutras; 2) a reflexão epistemológica deve incidir não nos conhecimentos em abstrato, mas nas práticas de conhecimento e seus impactos noutras práticas sociais" (Sousa Santos 2008: 154)

[iv] "La Ecología Política tiene un perfil bifronte pues, cual Jano moderno, posee por un lado una teoría política de la crisis ecológica, y por el otro, una teoría ecológica de la acción, las relaciones y las instituciones políticas" (Garrido Peña 2012: 24).

[v] Para Polanyi, "o significado substantivo do econômico decorre de a subsistência do homem depender da natureza e de seus semelhantes. Refere-se ao intercâmbio com seu meio natural e social, na medida em que isso resulta em lhe prover os meios para satisfazer a necessidade material" (Polanyi 2012a: 293). Uma ideia análoga já havia sido postulada por MARX (2011:60) "toda produção é apropriação da natureza pelo indivíduo no interior de e mediada por uma determinada forma de sociedade".

[vi] A segunda contradição do capitalismo está relacionada à forma destrutiva de apropriação da natureza por sistema econômico. A lógica de reprodução do sistema, baseada na acumulação infinita de capital, compromete a sua própria sustentabilidade em longo prazo.

2 - Objetivos

2.1 - Objetivo general

Contribuir al desarrollo teórico-metodológico de la Agroecología Política

2.2 - Objetivos específicos

1 – Presentar la Agroecología como enfoque para la intensificación productiva en agroecosistemas con metabolismos orgánicos (artículo 1)

2 – Describir y demonstrar el uso de un método de análisis económico-ecológico de agroecosistemas que les sitúe como construcciones socioecológicas contextualizadas en ambientes institucionales territorialmente referenciados y dinámicos (artículo 2)

3 - Analizar críticamente la internalización de la perspectiva agroecológica en las políticas de desarrollo rural en Brasil en el transcurso de las dos últimas décadas (artículo 3)

4 – Discutir el papel de políticas públicas en la creación y/o en el fortalecimiento de dispositivos de acción colectiva y en la conformación de una red sociotécnica de innovación agroecológica en un territorio rural del semiárido brasileño (artículo 4)

5 - Analizar el papel de una red sociotécnica de innovación agroecológica en un territorio rural del semiárido brasileño en la combinación sinérgica de recursos de políticas públicas con recursos endógenos para el impulso de trayectorias de intensificación agroecológica (artículo 5)

3 - Publicaciones

Las cinco publicaciones incluidas en este capítulo (artículos 1 - 5) han sido elaboradas para diferentes revistas y libros académicos. Tienen sus propias secciones, bibliografías y notas y no hacen referencia a otras partes de este dossier. So ellas:

Artículo 1: Agroecology and the restoration of organic metabolisms in agrifood systems

Referéncia de publicación: Petersen, P. in press. "Agroecology and the restoration of organic metabolisms in agrifood systems". In The Sage Handbook of Nature, organizado por Terry Marsden. London; New York: Routledge

Artículo 2: Lume: a method for economic-ecological analysis of agroecosystems

Referéncia de publicación: Agroecology and Sustainable Food Systems (en evaluación – Manuscript ID: WJSA-2017-0155) Coautor/es: Luciano Marçal da Silveira; Gabriel Bianconi Fernandes & Silvio Gomes de Almeida

Artículo 3: Institutionalization of the Agroecological Approach in Brazil: Advances and Challenges

Referéncia de publicación: Petersen, Paulo, Eros Marion Mussoi, e Fabio Dal Soglio. 2013. "Institutionalization of the Agroecological Approach in Brazil: Advances and Challenges". Agroecology and Sustainable Food Systems 37 (1): 103–14. doi:10.1080/10440046.2012.735632.

Artículo 4: Hidden Treasures: Reconnecting Culture and Nature in Rural Development Dynamics

Referéncia de publicación: Petersen, Paulo F. 2015. "Hidden Treasures: Reconnecting Culture and Nature in Rural Development Dynamics". In Constructing a New Framework for Rural

Development, organizado por Pierluigi Milone, Flaminia Ventura, e Jingzhong Ye, 22:157–94. Emerald Group Publishing Limited. doi:10.1108/S1057-192220150000022006.

Artículo 5: Agroecology, Public Policies and Labor-Driven Intensification: Alternative Development Trajectories in the Brazilian Semi-Arid Region

Referéncia de publicación: Petersen, P., e Silveira, L.M. 2017. "Agroecology, Public Policies and Labor-Driven Intensification: Alternative Development Trajectories in the Brazilian Semi-Arid Region". Sustainability 9 (4): 535. doi:10.3390/su9040535.

3.1 – Artículo 1 - Agroecology and the restoration of organic metabolisms in agrifood systems

Referéncia

Petersen, P. in press. "Agroecology and the restoration of organic metabolisms in agrifood systems". In *The Sage Handbook of Nature*, organizado por Terry Marsden. London ; New York: Routledge.

Agriculture by definition implies human intervention in the natural world. Technically speaking, it signifies the conversion of the ecosystem into an agroecosystem. The ecosystem is an ecological system whose reproduction is assured by the work of nature: in other words, by material cycles and energy flows primarily fed by solar radiation. For 95% of our history as a species we appropriated the fruits of nature's work through the practices of gathering, hunting and fishing. The level of human intervention in the ecosystem was minimal, in most cases limited to extracting selected elements from nature.

Around ten thousand years ago, the human relationship with the rest of the natural world began to change through the management of agroecosystems, inaugurating a new mode of appropriation and substantially altering the patterns of circulation of material and energy in the socioecological dynamics of obtaining, distributing and consuming foods and fibres.

This new strategy of interconnections between social and ecological processes released a set of human potentialities until then limited by the complete dependency of social life on ecosystem dynamics.

Known as the Neolithic Revolution, this period of history unfolded as a gradual process of *domestication of nature*. Expressed both at species level and at landscape level, domestication worked to channel ecological cycles and flows to meet social objectives, thus increasing efficiency and security in the procurement of natural goods necessary to human subsistence.

Both Environmental History and Ecological Economics posit that this historical period marks the transition from an extractive (or cynegetic) metabolism to an organic (or agrarian) metabolism (González de Molina & Toledo 2011) (see Box 1). Although solar radiation remains the primary source of energy in organic metabolisms, local ecological processes are substantially altered in relation to extractivist metabolic patterns.

Box 1 – Social metabolism

The original idea of social metabolism derives from Karl Marx (Foster 2011). In his formulation, metabolism corresponds to the labour process through which human society transforms external nature and, in so doing, transforms its own internal nature. The effects of the labour process on internal nature condition the social relations of production. In his own words, Marx teaches us that *Labour is, first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature* (Marx 1976: 283). This intuitive application of a concept taken from the natural sciences for the analysis of economic systems was developed in recent decades by ecological economists, especially after the formulations of Geogescu-Roegen (1973) on the entropic nature of conventional economic systems. According to the perspective of social metabolism, the relations between humanity and the rest of nature are analysed as an economic-ecological system composed by five main metabolic processes: appropriation, transformation, circulation, consumption and excretion. Pursuing this analytic approach revealed new perspectives concerning the articulation between natural sciences and social sciences, making clear that the idea of metabolism is not simply a metaphor. Among other aspects, this new interdisciplinary perspective has contributed to a better comprehension of the historical processes, objectively demonstrating the strong correlation between ecology unsustainability and social inequality in the dominant development models (Martinez-Alier 2005).

Codomestication and coproduction

Once converted into an agroecosystem, the ecosystem comes to be intentionally kept distant from its natural equilibrium. From this viewpoint, the agroecosystem is a system in disequilibrium, whose reproduction depends on the mutual and permanent association between *human work* and the *work of nature*. In other words, it is the result of the coproduction between the social and the natural (Toledo, cited in Ploeg 1993), meaning that it should be understood as an *economic-ecological system*.

Analysed from this perspective, agriculture can be defined as the social management of ecologically immature ecosystems with the objective of economically exploiting the high levels of primary net productivity found in the premature stages of ecological succession.[1] However, the economic advantage achieved by maintaining the immaturity of the ecosystems enters

into conflict with the ecological disadvantage generated by interference in the natural processes responsible for the reproduction of the structural integrity and functional dynamic of nature. This is because the *boons of nature*[2] essential to agriculture, such as soil fertility (and its continuous regeneration) and the regulation/control of populations of spontaneous species, are reduced or even eliminated with the increase of ecological immaturity of agroecosystems.[3]

The history of the world's agricultural systems can be interpreted in light of this constant tension between the economy and ecology of cultivated ecosystems. Mazoyer and Roudart (2001) produced a brilliant analysis of this historical perspective, demonstrating how different agroecosystems across the planet were shaped and evolved through dynamics of socioecological coproduction. In these dynamics, human work and the work of nature are closely integrated and generate a mutual feedback system, mobilizing and combining the 'boons of nature' to meet objectives linked to economic production and ecological reproduction simultaneously.

From the ecological viewpoint, the historical trajectories of sociotechnical innovation in agricultural systems were conditioned by the objective of balancing the advantages and disadvantages of ecosystemic immaturity. There are therefore social constructions shaped by the geographic and historical peculiarities of each agricultural system. In this sense, they imply processes of technical and social innovation informed by cycles of collective learning at local level, involving observation, interpretation, experimentation and evaluation. In this line of thinking, the history of agricultural systems can also be understood as a form of codomestication: humans domesticate nature and nature domesticates humans. In the words of Toledo and Bassols (2015), they are processes of the production of *culturalezas*, 'culture-natures.'

Over these trajectories of codomestication, better socioecological equilibriums are constructed through the continual upgrading of the structural and functional analogies between agroecosystems and pre-existing ecosystems. Not without good reason, the first civilizations developed and subsisted for centuries on agroecosystems structured in alluvial soils that retain a broad ecological similarity to the ecosystems on which they were based.[4]

In territorial terms, the conversion of forest ecosystems into agroecosystems became the most common situation across the planet. The first technical stage in this conversion was the shifting cultivation system, a method based on the replenishment of environmental fertility through the temporal and spatial alternation of agricultural plots at different levels of ecological maturity.[5] Though making extensive use of environmental resources, this technical

strategy remains historically viable under exceptional conditions in which agricultural communities have sufficient territorial endowment to keep land fallow for long periods.[6]

Labour-based intensification

Boserup (1981) showed that increases in population density that led to land shortages for a particular social group set off processes of sociotechnical innovations that were able to reconcile ecological sustainability with economic intensification. In Europe, this historical evolution involved the continuous shortening of fallow periods and eventually their complete elimination by the end of the Middle Ages.

In organic metabolisms, the syntax of agricultural intensification is related to the constant perfecting of local dynamics of coproduction. In other words, intensification is founded on improvements in the labour process within the context of agroecosystems and rural territories. The peculiarity of agriculture compared to other economic activities resides in the fact that its objects of work are elements (or *boons*) of nature (Ploeg 1993). This means that increases in production per object of work occur as a result of innovations in the forms of articulating human labour with the work of the rest of nature.

Put otherwise, it corresponds to the millenary and planetary-wide evolution of local relations of reciprocity between human beings and living nature (Ploeg 2011). From an even more radical, ontological perspective, it corresponds to the evolution of the forms of integration of the human being in nature – that is, in the web of life that composes the Biosphere (Capra 1996).

Reciprocity: a key mechanism in organic metabolisms

The relevance of reciprocity in the organization of organic metabolisms is not limited to the integration processes connecting human beings to the rest of nature – i.e., the actions of appropriation and excretion. It is also expressed in the metabolic functions performed in the social sphere, that is, in the transformation, circulation and consumption of natural goods.

Karl Polanyi (2012) describes the forms of social integration over the course of history, demonstrating that, alongside market exchange and redistribution, reciprocity is a key mechanism in the organisation of economic systems.[7] The central element in Polanyi's analysis is the idea that the combined functioning of these three forms of social integration depends on the presence of well-established institutional structures. From this viewpoint, the historical transformation of economic-ecological systems (like agroecosystems) should also be

comprehended as the evolution of the institutional structures responsible for the combined functioning of these three forms of social integration.[8]

The great metabolic transformation

In his seminal book *The Great Transformation*, Karl Polanyi (2000) analysed how market exchanges came to exert a growing influence on the regulation of metabolic flows from the eighteenth century onward in detriment to relations of reciprocity (among humans beings and between them and nature). The essential step for this historical change was the creation of social institutions that allowed more and more portions of nature to be valorised and exchanged through markets. As a result, human labour and land come to be conceived as commodities – or, in other words, as though produced for sale. In Polanyi's words: *The proposition is as utopian in respect to land as in respect to labour. The economic function is but one of many vital functions of land. It invests man's life with stability; […] And yet to separate land from man and to organize society in such a way as to satisfy the requirements of a real-estate market was a vital part of the utopian concept of a market economy* (Polanyi 2000: 214).

It is not the place to enter into detail concerning the conditions that enabled the institutional turn that cleared the way for the historical emergence and global dissemination of capitalism. This *great transformation* did not take the form of a historical rupture but gradually developed from the start of the sixteenth century when a world economy started to become established for the first time (Wallerstein 1974).

In pre-capitalist societies, social wealth was measured by the productivity of the land – or, in other words, of the association between the work of nature and human labour. Under capitalism, though, wealth became measured by the productivity of monetarily remunerated human labour. Moreover, as Karl Marx discerned (2014), the wealth produced became incorporated and objectified in the form of commodities. In a society organised in this way, the price-forming market assumes the role of the dominant institution of the economic system.[9]

The economic rationality imposed through this institutional turn induces the development of new forms of appropriating natural goods, altering the scale, speed and scope of the transformations of ecosystems.[10] From this viewpoint, rather than a new economic system or a new form of social division of labour, capitalism emerges as a new system of governance of the socioecological metabolism. In other words: *as a peculiar way of organizing nature* (Moore 2015: 58).

This radical change in the socioecological metabolism was anchored in a new intellectual paradigm founded on the ontological separation between humanity and the rest of nature. This Cartesian apprehension of reality was a necessary condition for the establishment of economies grounded in the idea of *domination of nature*, contrasting with the codomestication strategies that prevailed in earlier historical societies.

The metaphysical illusion of industrial metabolism

The great institutional transformation that paved the way for the development and rapid expansion of the metabolic pattern driven by capital was structured around two metaphysical axioms: the myth of the unlimited progress and anthropocentrism (Garrido et al. 2007). On one side, nature is conceived as an endless stock of resources able to be mobilized for the economic process. On the other hand, the human being is conceived as a self-referential entity that locates itself above nature in order to dominate it. However, *nature is finite and rebellious*: as well as becoming exhausted when exploited beyond its capacity to replenish itself, it refuse to *accept* being dominated passively.

Faced by the depletion of resources and the mechanisms of ecological resilience, a broad repertoire of strategies for appropriating the boons of nature was (and continues to be) developed in order to ensure the continuity of the expansive dynamic of capital.[11]

Here it is worth recalling that this new mode of production[12] first emerged in the era of European expansionism (Braudel 1997) when vast territories were incorporated into the appropriation frontiers by means of predatory extractivism (of timber and minerals) and the transformation of ecosystems into monocrop agroecosystems covering huge swathes of territory.[13] As well as the geographic expansion of the appropriation frontiers, a fact still present today in various regions of the planet like Brazilian Amazonia, this repertoire includes the development of new knowledge and technologies aimed at the identification, codification and rationalization of the boons of nature as a way of incorporating them into the wealth production process.[14]

A decisive element in this historical trajectory of appropriating nature was the mobilization of the natural work/energy accumulated through multi-millenary biogeological processes in the form of fossil fuels.[15] This technological innovation, which set the conditions for the Industrial Revolution in the eighteenth century, represented a watershed in the history of humanity.[16] By enabling metabolic activities to be disconnected from the ecological dynamics fed by solar

radiation, the use of fossil energy cleared the way for the development of a third metabolic pattern in human history: industrial metabolism (González de Molina & Toledo 2011).

From the first technological applications of fossil fuels, when coal was used to fuel steam engines in the English textile industries, two centuries were necessary for industrial metabolism to become fully established in the dynamics of functioning of the agroecosystems.

Agroecosystems as the setting for a Cartesian theatre

The rapid dissemination of the metabolic industrial pattern in the rural world from the second half of the twentieth century should be interpreted as a political project deliberately promoted to meet the new demands for reproducing capital.[17]

As harbinger of the promise to overcome the *backwardness* of agriculture and the rural world compared the urban-industrial world, this project was imposed after the Second World War, dominating politics, practice and theory (Ploeg et al. 2000) in the rhetoric guise of the modernization of agriculture.

This promise would be materialized through the rational use of land and other productive resources, guaranteeing production of the foods necessary for a rapidly expanding global population, while producing export revenues for national and regional economies, and promoting the social and economic integration of the agricultural sector with the overall development of modern societies. These effects would be achieved through the widespread uptake of a new technological matrix combining five main practices: 1) chemical fertilization and the use of industrial feeds and growth hormones; 2) chemical control of insect pests and diseases; 3) the intensive tilling of soils; 4) intensive irrigation; and; 5) the manipulation of the genomes of plants and domestic animals.

Although each of these practices performs a specific function in the ecological dynamics of agroecosystems, they only become functional when employed in different combinations with the rest. This interdependence leads to the development of highly inflexible technical systems, developed to be disseminated universally in the form of technological packages (Petersen et al. 2009).

This way of comprehending the ecological operation of agroecosystems is founded, therefore, on a mechanicist agronomic model that at a theoretical level presumes the possibility of total control over the natural dynamics through the employment of technologies scientifically defined with the assistance of the parametric method.[18]

The paradigmatic rupture imposed by the modernization project can be summarized as the substitution of the objective of domesticating through the domination of nature. Relations of ecological reciprocity, only possible in environments based on symmetric interaction, are abandoned, giving way to a pattern of relationship based on the human attempt to impose unilateral control over the dynamics of the rest of nature. A practical expression of this change of perspective is manifested in the new strategies adopted to manage agrobiodiversity: instead of adapting the genotypes of plants and domesticated animals to the local ecological peculiarities, the paradigm of modernization is based on the widespread use of genotypes developed in environments artificially controlled to obtain high levels of productivity.[19] However, for the varieties and races developed through genetic improvement to express their productive potential, optimal ecological conditions need to be provided through the deployment of other technologies making up technological packages (Table 2).

Table 2: Altering the endosomatic metabolism of domesticated species

The so-called *high-yield varieties and hybrids* are developed in optimal environmental conditions obtained through the use of synthetic fertilizers, irrigation systems and pesticides. As a result, the genotypes are subjected to selection pressures that render dispensable the action of genes conferring greater physiological adaptability to ecological variations – i.e. genes providing greater resilience to the effects of environmental stresses such as low availability of nutrients and water in the soils. Consequently the energy and nutrients invested in maintaining physiological strategies of ecosystemic adaptation – for example, the development of deep roots and the symbiotic association with soil organisms – are channelled instead towards the formation of the plant organs of commercial interest (Gliessman 2000). The genetic deactivation of these strategies means that the genotypes become structurally dependent on similar ecological conditions to those that generated the selection pressure during the genetic improvement process. In order for the genetic potential of high physical productivity to be manifested in commercial crops, therefore, the latter need to be grown in artificially produced environmental conditions. This is why the substitution of local varieties by commercial varieties entails the need for corresponding changes in practices for restoring fertility and maintaining health in agroecosystems. This forces farmers to become increasingly dependent on the technological packages of modernization. When applied to the development of animal genotypes, this approach leads to a dependency on commercial feeds and medicines, as well as the need to artificially alter the environmental conditions of farms to allow a higher proportion of the metabolic energy of livestock to be

channelled into economic production.

Through this change of focus, the relations of coproduction that guided the evolution of agricultural systems for millennia gave way to a metabolic pattern structurally dependent on industrial inputs and non-renewable energy sources. Unlike the earlier technical improvements, the technological arsenal of modernization increasingly disconnects agriculture from local ecosystems, making endogenous resources superfluous[20] and pushing agroecosystems into unprecedented levels of ecological immaturity.

Two long-term negative consequences arise from this ecological disconnection: 1) the agrifood systems become increasingly inefficient in their use of energy (Acker et al. 2013); 2) agriculture is converted into a powerful toxic agent harmful to nature (including human beings) (Carson 1962, Colborn et al. 1997).

In the Cartesian theatre of industrial agriculture, farmers lose their role as leading actors directing the scene. Following the script elaborated by science, external actors begin to steer the development of the setting by remote control through the markets.

Scientification,* commodification *and externalization in agroecosystems

The construction of the new agricultural paradigm in accordance with the theoretical postulates of the neoclassical economy set the historical conditions for the logic of capital to penetrate the agricultural world. Technical and economic parameters set by the agrarian sciences became the precondition for the routinization of agricultural work via the markets. In practice, this scientification of agricultural activities materializes in the substitution of technical strategies founded on the valorisation of endogenous resources with strategies dependent on the continuous input of exogenous resources. As a result, the ancient notion of the *art of locality* (Mendras 1970, cited in Ploeg et al. 2004), which aptly defined classic Agronomy, loses its theoretical and practice meaning, since the artisanal nature of agricultural work, as well as the peculiarities of ecosystems and the surrounding societies, lose their importance in the economic-ecological management of agroecosystems.

The notion of modern agriculture imposes an active negation of traditional agriculture and the art of locality (Shultz 1965).[21] Consequently, the process of modernization becomes assimilated as a progressive movement towards technologically and institutionally more complex and integrated forms of modern society (Long & Ploeg 2011). The idea of *modernizing*

agriculture takes on an equivalent meaning by integrating agroecosystems with the upstream market, through the dependence on industrial inputs and equipment, and downstream, through the scaling up of commercial production. As a result, both agricultural products and the resources needed for their production take on the rationale of the commodity.

This multifaceted commodification implies the externalization of operations from the production process with the transfer of the control of productive resources to external agents such as banks, manufacturing industries, input and equipment suppliers, technical assistance, and so on. Activities previously coordinated by farmers and their communities, based on relations of reciprocity, are substituted by others dependent on resources and services mobilized in the markets.

The growing loss of autonomy of farmers and agriculture as a whole is the corollary of the logical connection between scientification, commodification and externalization of agroecosystems. The combined effect of these processes has profound impacts on the reproduction strategies of agroecosystems. In the terms employed by Ploeg (1996), they involve the substitution of *relatively autonomous and historically guaranteed* strategies by others *dependent on the relations established in the markets*.

Analytically it is important to emphasize that agricultural modernization occurred as a form of subordinate integration of agriculture and the rural world to the general process of capitalist accumulation (Wanderley 2009). As well as expanding the frontiers extracting the boons of nature[22] and exploiting human labour, the modernization project engendered new forms of social division of labour between the rural world and the urban world, between agriculture and industry and between different agricultural establishments.

Capital-based intensification

Agriculture's incorporation of industrial metabolism created the objective conditions for the economic-ecological management of agroecosystems to reconcile two mutually exclusive trends that have developed over the course of history: increase in scale and intensification.

This unprecedented reconciliation of contrasting technical-economic strategies was made possible by the continuous replacement of labour (human and extra-human) by capital in the reproduction of agroecosystems. In other words, it involved the substitution of local dynamics of coproduction by growth factors purchased in the markets. In the first case, the biogeochemical cycles are organised at the level of the rural landscape based on the management of water and biodiversity (living or dead). The reproduction of the

agroecosystem is assured by the intensive investment in skilled labour informed by a body of contextualized knowledge. The end result of this style of management is the formation of a complex metabolism that involves the maintenance of dense economic-ecological webs activated through a strong input of collective action strategies based on relations of reciprocity.

In the second case, reproduction is assured by the importation of material and energy from outside the agroecosystem, configuring technical-economic management styles that involve the mechanical sequencing of management operations prescribed in technical protocols scientifically systemized outside the local socioecological contexts. The labour process is geared towards inducing the formation of simplified metabolisms characterized by linear flows of material and energy inputs and outputs from the agroecosystem. Consequently, reproduction becomes structurally dependent on technical-administrative relations established with external agents (from the market and the State), rendering the mechanisms of social and ecological reciprocity obsolete.

With the increasing dominance of commercial rationality over the governance of agroecosystem metabolisms, the physical productivities of industrial agriculture become ever more dependent on the mobilization of boons of nature appropriated beyond the physical boundaries of local ecosystems. Hence the agricultural labour process becomes mobilized by the constant and increasing input of matter and energy incorporated in commodities. In economic terms, this implies a rise in intermediate consumption and, consequently, a downward trend in added value per object of labour.

This logic of economic-ecological management governed by the price/cost ratio of the commodities that enter and leave agroecosystems tends to lead to a fall in profit margins, compelling farmers to combine strategies for intensification and scaling up production in order to obtain monetary income levels that match their economic expectations. Hence we can observe the incorporation into agriculture of the kind of Fordist production strategies previously adopted in manufacturing industry to increase the productivity of labour: progressive integration in commercial circuits, social division of work, substitution of production factors, productive specialization and economies of scale.

The emergence of imperial metabolic regimes

In the second half of the twentieth century, the rapid spread of agricultural modernization as a paradigm was accompanied by an unparalleled expansion of the world economy, including an

increase in the flows of capital and commodities across the entire planet. Agricultural technology and agricultural science are combined under the control of the markets that – precisely thanks to technology and science – have become globalized both upstream and downstream of agriculture. While science develops the technological patterns needed for the markets to operate at ever-expanding scales, the markets direct the courses taken by scientific and technological innovation in order to favour the growing accumulation of capital through the metabolic processes that link production to the consumption of foods (Petersen 2009).

Historically, this self-propelled dynamic of expanding industrial metabolism within agrifood systems gained momentum with the deregulation of agricultural markets, following the signature of the World Trade Organisation (WTO) Agreement on Agriculture in the mid-1990s, under the aegis of the neoliberal globalization project.

Faced with the new institutional arrangements that favour the intensification of flows of financial capital at global level, the agrifood systems became an ideal arena for companies from the agroindustrial sector to compete for market dominance. Making use of a practically unlimited supply of credit from the financial sector, large transnational conglomerates were formed through the rapid appropriation of small and medium-sized companies and mergers of larger companies.

A rapid shift of wealth and power occurred between agriculture and the industrial and financial sectors, creating the conditions for the emergence of a corporate agrifood system (McMichael 2009). The essence of the current phase of globalization of agricultural markets involves the imposition of a set of technical norms and institutional parameters that facilitate remote control of the technical-economic management of agroecosystems and, at a broader scale, of agrifood systems. This remote control takes the form of an imperial power exercised by the major agribusiness corporations (Ploeg 2008).[23]

In practice the growing mobility of financial capital seen in agrifood systems over recent decades, driven by neoliberal globalization (Bonanno & Cavalcanti 2011), has corresponded to an unparalleled intensification of the global flow of material and energy.[24] Commanded by and for capital, the transformation of the metabolic patterns of the agrifood systems enabled by the deepening commodification of the agricultural labour process and the liberalization of international trade show unmistakable signs of reaching their ecological and social limits.

Unequal exchange and closure of appropriation frontiers

By transforming into the main vector responsible for industrial metabolism in agrifood systems (González de Molina & Toledo 2011), the markets became more and more dominant in terms of shaping the institutional assemblages connecting food and fibre production to consumption, pushing aside other forms of social integration (in Polanyi's sense). As a result, agricultural economies became uprooted, losing their connectivity to the socioecological and cultural specificities of rural territories.

Physically enabled by the availability of cheap fossil fuels, this uprooting generated historically unparalleled levels of disconnection between the metabolic processes of appropriation and excretion in agrifood systems. Symptoms of the accentuation of this *metabolic rift* indicate that globalized agrifood systems are approaching their biophysical limits.

Representing opposite sides of the same coin, these limits are expressed through two complementary aspects. The first is the gradual exhaustion of the boons of nature appropriated by the economic process. The lengthy era of appropriation generated by high financial returns on relatively low investments in labour gave way to a historical period that combined a quickening decline in returns with disproportional increases in the efforts to obtain them (Davidson et al. 2014). In practice, this phenomenon is expressed in the rising prices of agricultural inputs and the need for increased use of these inputs to offset the loss of soil fertility and the increase in biotic imbalances, which need to be artificially counterbalanced in order for the physical productivity levels of agroecosystems to be sustained.[25]

The other aspect of biophysical limits are the massive levels of waste generated by globalized agrifood chains. The linear flows of material and energy that typify industrial metabolism separate appropriation from excretion in time and space, such that predatory extraction at one point generates accumulating flows of waste and pollution at the other. The imposition of this metabolic pattern through the project of agricultural modernization and its subsequent global dissemination under neoliberalism has led agrifood systems to assume a prominent role as a source of pollution across the planet over recent decades.[26]

This double pressure on the ecological base of agrifood systems corresponds to a closure of the frontiers of approriation, a process resulting from a deepening pattern of unequal exchange between human beings and the rest of nature, the origins of which date back to the colonial monocrops of the sixteenth century. Although this process is concealed by a dominant economic paradigm that deliberately ignores the biophysical materiality incorporated in flows

of commodities, the effects of global climate changes have emerged in the present historical moment as publicly visible symptoms of the limits of an institutional system that conceives nature as an inexhaustible supply of resources and as a limitless waste sink.[27]

Peasantry: the sociocultural base of organic metabolisms

The same institutional system that has severed the ties of reciprocity between humanity and the rest of nature instils patterns of unequal exchange within the social sphere. Over recent decades, the rise in relations that exploit paid human labour and appropriate unpaid human labour has been responsible for siphoning off increasing amounts of added value generated in agriculture to the agrifood empires. In practice the dynamics of industrial metabolism are expanding in detriment to the organic metabolisms reproduced in the modes of existence and production of peasant farming. Since these metabolic patterns are organised through highly contrasting ecological, economic and social principles, their overlapping in the same space and time generates territorial conflicts, or as González de Molina and Toledo (2011) propose, *intermetabolic conflicts*.

Having received broad political, ideological, financial and in many cases military support from State governments, the modernization project spread territorially, accelerating the depesatization[28] in countries of the North and South. For Hobsbawm (1994: 288-99, cited in Berstein 2009) *the most dramatic change in the second half of this century, and the one which cuts us forever from the world of the past, is the death of the peasantry*. Echoing the eminent English historian, a wide range of academic and political circles have predicted the *end of the peasantry* (Mendras 1967) as an inevitable destiny in the face of capitalism's encroachment into the rural world.

Empirical reality, however, shows that global agrarian history does not follow the destinies theoretically envisaged on the basis of the modernization paradigm. Instead of a single script of rural development determined by the forces of globalized and globalizing markets, what can be seen across all regions of the planet is the development of diverse trajectories of development of agroecosystems, influenced by locally written scripts and energized by the multiple creative forms of resistance and struggles for emancipation of peasant farmers.[29] A central element in this resistance is the continuous construction, improvement, amplification and defence of self-controlled base of local resources, composed through the mutual interconnections between boons of nature and institutional arrangements of social integration.

However much these resistances may appear irrelevant when analysed in isolation, taken in conjunction their practices point to consistent ways of building local solutions to serious global problems caused by modern agrifood systems. These practices reproduce relatively autonomous and sustainable agrarian metabolisms, shaped by technical-institutional assemblages that organise human work in accordance with fundamental elements also present in the organisation of the work of nature: diversity; the cyclical nature of processes; adaptive flexibility; interdependence; and ties of reciprocity and cooperation.

This set of fundamental elements is inscribed in the biocultural memories (or cultural repertoires) of peasant communities. At the same time as they challenge the economic, agronomic and sociological postulates of modernization, their practical application in the process of agricultural work fosters the reconciliation between (agri)cultures and natures as elements that are structured together dialectically, revalorising the decentralized dynamics of coproduction that have nourished heterogenesis of the world for millennia (Petersen, Weid & Fernandes 2009).

Unlike the diagnosis presented by Hobsbawn, these biocultural memories remain alive and active, emerging in the present historical setting as links between the past, present and future of humanity. The protection and cultivation of these memories are urgent tasks that require the development of social institutions informed by a science grounded in epistemological, conceptual and methodological principles that can move beyond the Cartesian splitting of nature between human and non-human worlds.

Agroecology: science in service of repesantization

In order for peasant farming to be socially recognised and promoted, Science needs to approach the empirical reality from angles very different from those proposed by the theory of modernization. Changes in this direction are under way: instead of continuing to decree the inexorable disappearance of peasant agriculture, the social sciences have contributed to an awareness that peasants are here to stay, and that the world would be much worse off had they effectively disappeared. Rather than continuing to place trust in the human capacity to dominate nature, the agrarian sciences are gradually recognizing that agriculture is the art of coproduction and that peasant farmers are the great masters of this art (Petersen 2009).

As a scientific approach, Agroecology was born from the merging of two sciences that had sustained a tense relationship for much of the twentieth century: Agronomy and Ecology. While the former was concerned with the development of agricultural practices more and

more detached from nature, the latter was primarily interested in the study of natural systems (Gliessman 2000). The interconnections generated between the two sciences, which eventually led to a new synthesis, involved a convergence between the work of ecologists interested in studying agricultural systems and the work agronomists investing in an ecological approach to solving technical problems in agriculture.[30]

Wezel and Soldat (2009) provide a historical analysis of Agroecology, observing that as early as the end of the 1920s, academic works were referring to the application of an ecological perspective to agricultural crop management. Since then, the agroecological approach has widened its aims, looking to explore the ecological interactions among an agroecosystem's subsystems and, subsequently, at an even broader level, the economic-ecological interactions established in the context of agrifood systems.

This interdisciplinary, multilevel and multidimensional feature distinguishes the agroecological approach in various ways from the dominant paradigm of agricultural modernization. Firstly because (1) the construction of agroecological knowledge is contextualized in the agrarian realities where it will be employed. This construction is focused essentially on (2) the promotion of ecological balances at the scale of the agricultural landscape,[31] so as to (3) mobilize territorial ecological capital for use in the agricultural work process, (4) stimulating endogenous trajectories of technical innovation that simultaneously enable (5) the maintenance and/or increase in the physical productivity of crops and livestock breeds and the (6) reduction in intermediary consumption, resulting in (7) production with a higher added value, (8) its appropriation by farming families and (9) the retaining of this value within the territory. The social wealth generated in the process (10) feeds back into endogeneity, (11) creating new margins of autonomy for the continuous production of innovations.

Secondly because (12) the social process of sociotechnical innovation is not determined exclusively by knowledge originating from the academy, which implies (13) the structuring of multi-actor sociotechnical networks at territorial level, (14) responsible for the creation of fertile social environments for evolving the dialogue between scientific-academic knowledge and popular wisdom.[32] Through these environments, (15) the social agency of peasants and their organisations is recognised and developed, thereby (16) strengthening social capital, (17) revitalising practices of social reciprocity, (18) enhancing local institution arrangements, (19) enabling greater levels of local governance over markets, and finally (20) diversifying economic activities in the territory (Petersen 2013).

A practice, a science and a social movement

Agroecology is becoming increasingly consolidated worldwide as a critical theory that formulates a radical questioning of industrial agriculture, simultaneously providing the conceptual and methodological bases for the development of economically efficient, socially just and ecologically sustainable agrifood systems. As a social practice, agroecology is expressed in the diversity and creativity of the forms of resistance and struggle found among peasant farmers, in particular their strategies for constructing autonomy from the input and labour markets by recuperating mechanisms of ecological and social reciprocity. As a social movement, agroecology mobilizes actors involved practically and theoretically in its construction, as well as mobilizing growing sectors of the population to fight for social justice, collective health, food and nutritional sovereignty and security, a solidary and ecological economy, equity between genders and more balanced relations between the rural world and the cities. In essence, agroecology produces a synergy between three forms of understanding, condensing its analytic approach, its operational capacity and its political advocacy into an indivisible whole.

Over the course of the last ten years agroecology has acquired increasing academic and institutional recognition. An extensive meta-analysis of studies carried out in countries from every continent demonstrated that agroecology-based production achieves physical yields equal or superior to those of industrial agriculture (Badgley et al. 2007). As well as confirming the technical possibility of meeting the rising global demand for food without the use of pesticides and transgenic crops, this collection of studies emphasizes that the increases in production achieved through the agroecological approach can be attained without the need to deforest land for more farmland. Since the world food crisis of 2008, in fact, various United Nations bodies have published important documents confirming the notion that the agroecological approach to agricultural intensification offers consistent responses to the current accentuation, global spread and mutual interweaving of food, energy, ecological, economic and climatic crises (IAASTD 2009, De Schutter 2011, HLPE 2012, UNCTAD 2013).

Through a political economic critique of the productivist and anti-democratic approach of the globalized agrifood systems, rural social movements working under the umbrella of Via Campesina have championed agroecology as a means of fully realizing the human right to food, affirming the concept of food sovereignty as the *right of peoples to healthy and culturally appropriate food, produced through ecologically sustainable methods, and to define their own foods and production systems* (FFS 2007).

Representatives from civil society organisations present at the Global and Regional Seminars on Agroecology run by the United Nations Food and Agriculture Organization (FAO), promoted as part of the International Year of Family Farming, also stressed the political dimension of agroecology, manifesting their rejection of all attempts to reduce the agroecological proposal to a set of technologies designed to soften the negative environmental impacts of industrial agriculture. Along these lines, they argue that the notions of *climate-smart agriculture* and *sustainable intensification* that have become fashionable in international debates must not be confused with the agroecological proposal. Neither should agroecology be reduced to a proposal oriented towards organizing a niche market of organic products to the benefit of a few producers and consumers (Petersen & Londres 2015).

An intermetabolic conflict at global scale

One of the main lessons from the study of the history of agriculture is that the superseding of one pattern of technical and economic organization of agroecosystems by another has never occurred as an automatic outcome of new technological discoveries. The large-scale adoption of technical innovations tends to run into strong political-institutional and cultural obstacles, even when these new technologies have already shown a capacity to provide solutions to some of the deep dilemmas faced by societies. This is why agroecology remains limited to niches of social innovation, posing no threat to the institutional bases that sustain the industrial metabolic regime imposed by food empires. This is despite the fact that the latter is increasingly linked to the risks of socioecological collapse now evident within the *Anthropocene* era, particularly since the second half of the twentieth century, including an exponential increase in the negative interactions between human beings and the rest of nature, a period known as the *Great Acceleration* (Costanza et al. 2007).

The powerful institutional barriers to the advance of agroecology are closely associated with the ideological triumph of the dominant narrative concerning the globalized agrifood system. By diluting the social and political significance of the converging global crises (George 2012), this narrative seeks to attribute a strictly technical character to the advocated solutions, always associated with the expansive dynamics of the circuits of capital accumulation.[33] As Holt-Gimenez (2010) astutely pointed out, agroecology directly contradicts the logical of capital reproduction by reducing (or eliminating) the use of agrochemicals, by observing the local genetic resources and by depending on the peasantry. The first two factors generate autonomy from commercial relations, while the latter possesses a class logic. For the author,

supporting and strengthening the development of an independent peasantry always was unforgivable for the wealthy classes.

The conflict between industrial metabolism and organic metabolism in agrifood systems is thus a clear contemporary expression of class struggle. However, this class struggle over agriculture and food assumes specific structural forms insofar as capital and labour are dialectically interconnected, forming an organic whole with nature.

Renewing natural and social contracts

By contributing to the re-establishment and/or enhancement of dynamics of coproduction (or ecological reciprocity), agroecology supports repesantization processes, restoring the precedence of labour over capital in the metabolic functioning of agroecosystems. It also simultaneously mobilizes organised forms of collective action for the construction, defence and governance of common goods at territorial level, encouraging the reactivation of social reciprocity, an element intrinsic to the peasant mode of production.

By renewing the ties of reciprocity in social exchanges and in exchanges with nature, the agroecological approach contributes to the embedding of rural economies (in Polanyi's sense) in social capital and ecological capital, destroying the imperial power of financial capital over the metabolism of agrifood systems. From this viewpoint, agroecology indicates paths consistent with endogenous rural development (Ploeg & Dijk 1995).

Paraphrasing Holloway (2003), these paths widen the margins of manoeuvre for *change the world without taking power*. As the Spanish poet Antonio Machado put it beautifully, *these are paths made by walking*. This was also perceived at the very start of the twentieth century by Chayanov when he described the peasant as a *subject that constructs his or her own existence*. These observations have wide-ranging political and epistemological consequences.

The structural solution to the multifaceted agrarian crisis now spreading and deepening worldwide demands radical reformulations of the institutional frameworks that regulate the metabolism of agrifood systems. As the Brazilian theologian Leonardo Boff says (2016), we need to forge a new *natural contract* with the Earth. Every contract presumes the existence of reciprocity and the mutual recognition of rights between the parties involved. Although rejected for more than a century and a half by scientific and political institutions, peasant farming has emerged during this historical period as the main guarantor of this contract between humanity and the rest of nature. It forms part of its inner nature to respect and protect this contract with outer nature. And it is also a vital part of its inner nature to defend

the *social contract*, instituting mechanisms of community coexistence in defence of the common goods.

By helping decipher the mystery of peasant agriculture in the twenty-first century (Ploeg 2008), agroecology illuminates more promising horizons for the future of humanity. The main political challenge posed at this historical juncture resides in the creation of a collective will capable of channelling and synergizing the creative forces emergent in rural areas and in the academy, working to restore organic metabolisms through a new social contract that attributes a central role to the work dedicated to reproducing life and to agreed forms of coexistence with the rest of nature, regulated by the dynamics of coproduction and codomestication.

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Notes

[1] Ecologically immature ecosystems possess higher rates of net productivity than mature ecosystems. In more advanced successional stages (higher maturity), the solar energy captured through photosynthesis is channelled primarily towards the reproduction of the ecosystem itself, resulting in low levels of biomass accumulation.

[2] For native Andean peoples, the *boons of nature (bondades de la naturaleza, in Spanish)* correspond to what environmental economics conceives as *natural resources and ecological (or ecosystemic) services.*

[3] When compared with ecological mature ecosystems, immature ecosystems possess more open nutrient cycles and display more pronounced and unpredictable population fluctuations (Dover & Talbot 1992). The ecological challenges posed by agroecosystems have stimulated the inventiveness of farmers for thousands of years, prompting them to develop technical strategies for replenishing environmental fertility and maintaining the health of crops and livestock.

[4] As well as producing locally domesticated species (especially cereals), fertility is restored in agroecosystems based on alluvial farming is achieved through the deposit of sediments carried by the river floods.

[5] In this case, the advantages of the ecological immaturity of ecosystems are explored for a limited time after which economic productivity declines. This is the moment when the ecosystem is left to rest in order for the process of ecological succession to restore environmental fertility.

[6] Though responsible for the conservation of rural landscapes for generations, many of these communities are being prevented from adopting the fallow system by environmental legislation formulated from a preservationist perspective – that is, an approach that separates nature from society as a strategy of environmental conservation. The contradiction in this strategy stems from the fact that it penalizes those communities that have acted for generations as guardians of biodiversity and associated ecological services.

[7] This organisation involves the coordination of movements of goods and services within society in order to overcome the effect of differentials of time, space and occupation. According to the author, *regional differences within a territory, the time span between sowing and harvesting, or the specialization of labor is overcome by whatever movements of the respective crops, manufactures, and labor make their distribution more effective* (Polanyi 2012: 83).

[8] Institutions set the rules of the game in a society (North 1990) and correspond to the intangible dimension of socioecological metabolism (González de Molina & Toledo 2011). This means that the metabolic patterns in a given society are conditioned by the combination of hardware (the biophysical materiality of matter and energy flows) and software (the rules of social organisation).

[9] Every society defines its priorities in the way it decides on the value of things and relations. A society's rules for the production of wealth (and for the reproduction of power) are conditioned by this socially agreed ethical-political judgment. Under capitalism, value is determined by the productivity of paid labour in the production of commodities. The peculiarity of the market economy is that the social recognition of labour and the value of its products are determined by an institutional structure that adopts money as the main link in social integration.

[10] After this period, levels of deforestation equivalent to what had once taking place over centuries now occurred in decades or even years. To take one example: two hundred years were required to deforest 12,000 hectares in the north of France from the start of the twelfth century. Four hundred years later, around 1650, the same surface area would be deforested in just one year for sugar cane plantations in Brazil's Atlantic Rainforest region (Moore 2007).

[11] As well as the appropriation of the work of nature, the reproduction of capital depends on the appropriation of unpaid human labour necessary to the functioning of the economic system as a whole. This applies especially to the work dedicated to social reproduction, mostly performed by women. Hence the critique of capitalism developed by Feminist Economics (Mies 1986, cited in Moore 2015). The appropriation of the products of peasant labour also perform an important function in a market economy (Wanderley 1985). Hence the reproduction of capital depends on the constant actualization of strategies of exploitation (of paid human labour) and appropriation (of the work of nature and unpaid human labour).

[12] Mode of production, in the sense elaborated by Karl Marx (1867/2014), that is, *the set of relations between the agents of production and between them and nature*.

[13] It is also worth recalling that this period of rapid expansion of the frontiers of ecological appropriation occurred concomitantly with the expansion of the frontier of social exploitation through the mobilization of slave labour in European colonies in Africa. Without doubt the combination of broad frontiers of ecological appropriation and social exploitation led to unprecedented levels of capital (and power) accumulation, paving the way for the development of capitalism's institutional bases (Braudel 1997).

[14] The global imposition of a system of weights and measures was a necessary condition for the boons of nature to be able to become standardized and quantified, enabling their valorisation and exchange through commercial rules. The broadening of the frontiers of appropriation thus depended on the creation and imposition of universal languages for rationalizing nature, like the metric system (Alder 1995). It is much for this reason that Marx (1867/2014) recognized modern science as a *productive force* commanded by the logic of the reproduction of capital.

[15] Metaphorically, fossil fuels correspond to *photosynthesis bottled* millions of years ago. In accordance with the Second Law of Thermodynamics (the law of entropy), once used, i.e. *unbottled*, fossil energy is dissipated, meaning it cannot be reutilized subsequently in another labour process.

[16] The industrial revolution can be understood to emerge historically from the interaction of two processes: the bourgeois revolution and the scientific revolution, the former being understood as the imposition of the instrumental rationality of the markets to the organisation of social life, and the latter as the predominance of the vision of nature as a system endowed with a rational structure (Furtado 1978).

[17] The rapid dissemination of this project in Third World countries started in the 1950s within the framework of the so-called *Green Revolution*, a process whose denomination leaves no room for doubt concerning its eminently political and ideological character. In displacing the social and political meaning of the fights against famine and poverty, the narrative of the modernization project seeks to depoliticize these questions by treating them in strictly technical terms. The revolution's 'greenness' in fact reflects a contrast with the 'red peril,' especially after the Communist Revolution in China, in 1949, marked by large-scale involvement of the peasantry.

[18] Informed by the mechanicist paradigm, modern Agronomy conceives nature as the *setting for a Cartesian theatre* that can be deciphered and controlled with the assistance of production functions (Ploeg 2003). Founded on the parametric method, these functions specify linear relations between the use of varied levels of inputs and achieving corresponding levels of production. In this way, they seek to define the optimal levels for the use of inputs, aiming to maximize the economic results of production. The practices associated with the notion of *precision agriculture* are the maximum expression of the influence of the mechanicist paradigm on agroecosystem management.

[19] Average yields from commercial fields of corn in the United States more than quadrupled between 1935 and 1980 with the use of hybrid varieties (Kloppenburg 1988).

[20] By rendering local varieties and breeds superfluous, modernization's technological packages unleashed rapid processes of genetic erosion, destroying invaluable forms of biocultural heritage developed over the course of thousands of years in all corners of the planet by farmers working assiduously in close interaction with the dynamics of nature.

[21] Theodore Shultz, one of the leading theorists of the modernization paradigm, explains this idea in the opening passages of his best known work: *the man who performs agricultural activity in an identical way to his ancestors cannot produce much food, despite the wealth of the land or the intensity of his work. […] This study proposes to show that there is a logical economic basis for the fact that traditional agriculture, employing just the production factors available to it, is incapable of growth...* (Shultz 1965: 15 and 17).

[22] As well as the continuing horizontal expansion of the frontiers extracting the boons of nature with the incorporation of new territories into the economic rationality of capitalist agriculture, the modernization project also allowed the frontiers to expand vertically, with the mobilization of mineral resources – fossil fuels, water and nutrient-supplying rocks – through metabolic flows.

[23] In practice, the food empires have taken shape through the conquest of territories that remain relatively independent in terms of regulation of their agrifood systems, connecting them through the metabolic flows governed by the logic of financial capital, thereby ensuring the control and capacity for wealth appropriation generated in the stages of producing, processing and distributing foods. According to Ploeg (2008), what specifies and assures this imperial power over the metabolism of modern agrifood systems is the combination of two ordering principles: a) the global financial flows enabled by deregulation of the international markets; b) the logic of the assembly line imposed in the chain established between the production and consumption of foods, enabled by the standardization of scientifically-backed technical procedures and by political-institutional rules indifferently imposed on distinct socioenvironmental and cultural contexts.

[24] The mobility of capital enables the conversion of capital invested in material goods into money for its subsequent transfer to other applications. According to Delgado (2012: 45 and 46), *the basic function of financial circulation is the retransformation of capital, unfreezing it from its fixed applications so that it can flow unrestrictedly in the financial circuit...* From this viewpoint, under the aegis of capitalism, the flows of matter and energy and the flows of capital form an organic whole in which one flux implies the other.

[25] The emergence of herbicide-tolerant wild plants and antibiotic-resistant pathogenic microorganisms are perhaps the most visible examples of nature's capacity to react to the mechanisms of ecological domination imposed by the technologies of industrial agriculture. In the face of this rebellion from nature agroecosystems are becoming increasingly dependent on external inputs (and energy) in order to avoid – at least temporarily – falls in the productivity of commercial crops and livestock.

[26] The energetic – and chemical – intensity of industrial metabolism, as well as the elimination of the forest coverage for the expansion of monocrops in vast territories contribute to the high levels of toxic contamination, the eutrophication of bodies of water and the emission of greenhouse gases.

[27] The growing inefficiency in the use of energy in agroecosystems is also well-documented evidence of the divergence between the economy and ecology of industrial agriculture (Acker et al. 2013).

[28] Depesantization processes occur at quantitative and qualitative levels. The former case corresponds to the dissemination of agroecosystems governed by capitalist logic in territories previously occupied by agroecosystems governed by peasant logic. The latter case refers to the growing commercialization of agroecosystems managed by peasants.

[29] This capacity of peasant resistance to the advance of the processes of commoditization in agriculture was identified in the first quarter of the twentieth century by Chayanov (1981 [1924]) who argued that although peasant-managed agroecosystems are influenced by the capitalist context within which they operate, they are not directly governed by them (Ploeg 2013).

[30] Agroecology is founded on the use of genotypes adapted to the local socioecological contexts for the structuring of biological diversified and complex agroecosystems, composed of multicrops, agroforestry systems, crop-livestock integration and other strategies designed to establish synergies and complementarities between the biotic components. Through these strategies, solar radiation, water and locally available nutrients and the natural processes of biotic regulation (of insect-pest populations, weeds and pathogenic microorganisms) are valued in the process of agricultural labour, reducing or eliminating the need for the use of external inputs for the reproduction of agroecosystems.

[31] The dominant approach in the agrarian sciences is focused on solving specific problems of agroecosystems, such as the incidence of insects-pests and pathogenic organisms, nutrient deficiencies, water shortages and other growth factors. These specific problems are

considered limiting factors to physical productivity to be resolved through specific technologies capable of being used in all kinds of socioecological contexts through technological packages. Agroecology sets out from the understanding that these problems are not causes but symptoms of systemic imbalances. The agroecological management approach is focused on the establishment and maintenance of local ecological processes capable of reproducing systemic fertility. From this viewpoint, agroecology is founded on a radical critique of the mechanicist epistemology responsible for consolidating a representation of nature in the agrarian sciences incompatible with the economic-ecological rationalities present in peasant farming.

[32] According to the Multilevel Perspective to the analysis of sociotechnical transitions, these social environments can be likened to niches of innovation – that is, multi-actor sociotechnical networks that differ from the frameworks prevalent in the dominant sociotechnical regime, forming protected spaces where novel solutions can be allowed to mature through successive cycles of experimentation and learning (Wiskerke & Ploeg 2004).

[33] The form in which the origin of a crisis is conceptualized is related to the means chosen to confront it. It is along these lines that Moore (2015) calls attention to the conceptual imprecision of the so-called *Anthropocene era*, since this label contributes to concealing the power structures actually responsible for the negative effects of the historical emergence and global dissemination of industrial metabolism. *Touching the sore point*, the author asks whether it would not be more appropriate to call this historical period the *Capitalocene*. From this point of view, the convergence and spread of crises cannot be understood without taking into account the progressive closure of the frontiers extracting the boons of nature driven by the unlimited accumulation of capital. *If capitalism is an economy of unpaid costs, the bills are overdue* (ibid: 276).

3.2 - Artículo 2 - Lume: a method for economic-ecological analysis of agroecosystems

REFERÉNCIA

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ABSTRACT

The overwhelming empirical evidence of the failure of productivist models, which transplanted industry’s technical-economic approach to agriculture, have put the principle of sustainability onto the agenda of academic debates, social movements and public policies. Two polarizing questions emerge from these debates: first, the role and place of family farming in the reconfiguration of the patterns of occupying and managing agrarian spaces; and second, agroecology as a scientific-technological approach that can reconnect agricultural to the dynamics of ecosystems and reorganize agrifood systems so that they respond to the contemporary social aspirations and future demands for food in sufficient quantity, quality and diversity. Despite the growing social and political-institutional recognition of family farming and agroecology, there is still a dearth of analytic tools able to apprehend the economic and ecological rationalities that reveal the superiority of family-managed agroecosystems compared to the entrepreneurial logic informing agrarian capitalism. The method presented here seeks to help fill this lacuna. Its development was driven by the need to give visibility to economic, ecological and political relations that singularize the modes of production and lives of family farmers that have been historically concealed or distorted by conventional economic theory.

Keywords: agroecosystem, economic-ecological analysis, peasant economy, critical economics, participatory methodology, agroecology

Knowledge of reality is a light that always
casts a shadow in some nook or cranny
Gaston Bachelard (2002:25)

1- Introduction

Over the course of the last century, especially after the 1960s, economic thought concerning agriculture experienced a paradigm shift, resulting in the adoption of an analytic viewpoint very different to the kind previously employed in the description and analysis of wealth flows in agrifood systems. As well as reflecting the emergence of new trends in agricultural development, this change in theoretical framework also played an important role as a material force[11] propelling these same trends. This phenomenon occurred during the historical emergence of the agricultural modernization paradigm, a theoretical construct consistently molded on the synergetic combination of a technical-agronomic paradigm still under construction[2] and orthodox economic theory.

Agricultural modernization consists of transplanting the technical-economic logic inaugurated during the industrial revolution, some two centuries earlier, to contemporary agriculture. Aided by new farming technologies, various strategies for increasing labor productivity typical of industrial Fordism began to be employed in agricultural fields: the substitution of endogenous production factors by exogenous inputs, progressive integration in vertical market chains, the social division of labor, productive specialization and upscaling (Remmers 1998; Marsden 1992).

Analyzed from the perspective of political economy, this rapid transition from the predominance of organic metabolisms to industrial metabolisms in agrifood systems during the second half of the twentieth century (González de Molina & Toledo 2011) can be viewed as a political-institutional project designed to integrate the agricultural sector into broader process of accumulation, whereby agricultural products, as well as the resources necessary to their production, are subordinated to the capital cycle, taking on the commodity logic intrinsic to the latter (Wanderley 2009).

The social legitimacy of this project was actively promoted through powerful ideological mechanisms. Along with insisting on the need to transform so-called traditional farming, depicted as backward, this propaganda disseminated a positive image of the entrepreneurial-oriented farmer as the only agent possessing any real economic rationality (Schultz 1983).

With the propagation of this ideology, it became commonplace to take the modernization of agriculture to signify its integration with the upstream market, through the acquisition of inputs, equipment and services, and the downstream market, through the upscaling of commercial production. In essence, the aim was to transform agriculture into a branch of the chemical-mechanical industry.

This imposition of the premises of neoclassical economics on agriculture placed the sphere of circulation and subjective choice of agents at the hub of economic relations, the reason why agriculture has been studied and promoted solely as agribusiness ever since (Davis & Goldberg 1957). Agribusiness groups assumed an increasingly hegemonic role in shaping agrifood systems (McMichael 2006), steadily increasing the commodification of production factors and foods (Magdoff 2012) in detriment to other mechanisms of appropriating nature and social integration (Polanyi 2012) historically responsible for shaping the economic flows linking food production to food consumption. As a result, agriculture became uprooted, losing its reference to the socioecological and cultural specificities of rural territories.

However, nature rebels against the practical application of theories that contravene its laws. In the name of the supposed economic superiority of agribusiness, the attempt to replace the cyclical and complex nature of ecological processes in agricultural with linear flows of matter and energy has generated environmental costs[3] (Kimbrell 2002) and social costs (Weis 2007) that have proved devastating for contemporary societies.

In response to the deepening socioenvironmental crisis caused by the global spread of industrial-based farming, agroecology emerged in the 1980s with the aim of establishing the theoretical-conceptual bases of what was then called 'alternative agriculture' (Hecht 1987). Originally defined as the "application of ecological concepts and principles to the design and management of sustainable agroecosystems" (Gliessman 2000), agroecology resulted from the synthesis between agronomy and ecology, two sciences that maintained a tense relationship with each other for much of the twentieth century (ibid). Furthermore, it incorporates an epistemological perspective that breaks with the positivism of conventional science (Norgaard 1987) by recognizing and integrating biocultural knowledge into its methodology for building knowledge on agroecosystems (Toledo & Barrera-Bassols 2015).

From the 1990s, agroecology expanded the scope of its object of study from local-level agroecosystems to agrifood systems (Wezel & Soldat 2009), comprehended as networks for producing, processing, distributing and consuming food that are structured from the local/territorial level to the global. Due to this broader perspective, agroecology is currently

defined as “the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions”(Francis et al. 2003: 100). This much wider viewpoint was a decisive factor in the establishment of strategic alliances between agroecologists and different social forces that implicitly or explicitly resist the globalized agrifood regime (Pimbert 2015), while also contributing to the local construction of concrete emancipatory alternatives to its imperial order (Ploeg 2008; Rosset & Martínez-Torres 2012).

As a result of this evolution, agroecology came to be understood in three interconnected senses: as a science, as a practice and as a social movement (Wezel et al. 2009). In essence, agroecology’s development involved the synergetic combination of these three forms of understanding, condensing its analytic focus, operational capacity and political advocacy into one seamless whole (Petersen 2013; Méndez, Bacon & Cohen 2013).

By stimulating the synergetic interaction between social movements and academic research committed to achieving structural transformations to the dominant agrifood system (Levidow, Pimbert & Vanloqueren 2014), the agroecological field – to employ Bourdieu's sense of the term (2011) – adopts a stance directly opposite to the technical, economic, sociological and cultural premises that provide the theoretical underpinning to the ‘long green revolution’ (Patel 2013). This radical critical stance can be summarized as the defense of peasant farming as the sociocultural base of agroecology (Sevilla Guzman & González de Molina 1993; Altieri & Nicholls 2010; Ploeg 2012; International Forum for Agroecology 2015).

Given its evolutionary trajectory, the frontiers of knowledge explicitly identified with agroecology have naturally expanded as the ecological rationality of peasant production has become discernible (Toledo 1990) and its valorization clearly evinced in the design of sustainable agroecosystems (Altieri 2008). Identified through bibliometric analyses (Wezel & Soldat 2009), this aspect has encouraged some authors to question the limited scope of the founding principles of agroecology (Ikerd 2009), essentially linked to agroecosystem management strategies, while other authors have sought to clarify its socioeconomic principles (Dumont et al. 2016).

Whether because of the expansion of its object of study and its configuration as a science supported by an extended community of peers (Funtowicz & Ravetz 2000), or because of the risks associated with diluting its transformative critical perspective (Levidow, Pimbert & Vanloqueren 2014), this effort to consolidate agroecology’s sociological and economic foundations has emerged today as a simultaneously intellectual and political challenge.

From an epistemological perspective, the incorporation of key principles from the social sciences into the process of building agroecological knowledge should not be understood as a simple addition to the founding principles of agroecology. Given the coevolutionary nature of agroecosystems (Norgaard 2015), we need to transcend this kind of exercise in 'green arithmetic,' as Moore (2015) defines the dominant line of environmental thought, conditioned by the Cartesian dualism that apprehends nature and society as ontologically independent entities. On this point, Garrido Peña et al. (2007) develop a radical critique of the core notions that contributed to the crystallization of the 'human being/nature' binarism in the founding epistemology of the social sciences, and effectively concealed the physic-biological bases of social organizations.[4]

Meeting this challenge thus presumes the development of theoretical-conceptual and methodological approaches that enable the sociomaterial real life situations of agroecosystems and agrifood systems to be interpreted as the outcome of the co-production between nature and social organizations. Among other reasons, this is essential to ensure that the incorporation of social scientific principles into agroecological analysis does not become a mere exercise in idealism. By hindering the comprehension of the economic-ecological rationalities of peasant farming, idealist perspectives prevent the analysis from converging with concrete reality and allowing an effective dialogue between different knowledges and skills in the construction of agroecological knowledge.

Looking to contribute to this process, the article presents an economic-ecological method for analyzing agroecosystems. Its development is founded precisely on observing a lack of tools for systemic analysis of the economic and ecological relations that singularize the peasant modes of production and life that have been hidden or disfigured by conventional economic theory.

As a proposal for analyzing the processes involved in appropriating and converting ecological goods into economic goods for their later distribution within the social sphere, the method seeks to respond to two epistemological challenges:

1) overcome the rigid boundary established between the social sciences and the biological sciences through their affirmation of the *human being/nature* binarism organizing modern science and its institutions;

2) revalorize and reintegrate non-academic knowledge into formal processes of knowledge production concerning agrifood systems, agrarian realities in particular territories, and rural development dynamics.

The contents and configuration of the contribution presented here express the core elements of a proposal elaborated over the course of several years under the leadership of the article's authors.[5] Continuous enhancement of the method was enabled by comparing it to the reality of family farming in different regional contexts in Brazil, especially in those territories where AS-PTA is active,[6] an institution to which all the authors are affiliated. It has also benefitted from the input of organizations linked to the National Agroecology Alliance (*Articulação Nacional de Agroecologia*: ANA) and the Brazilian Semi-Arid Alliance (*Articulação Semiárido Brasileiro*: ASA), national and regional-level networks, respectively, in which AS-PTA participates.

Although the method was originally conceived to contrast the economic performance of agroecosystems managed according to agroecological principles with the performance of traditional agroecosystems and/or those managed according to the technical precepts of modernization (Gomes de Almeida 2001; Gomes de Almeida & Fernandes 2005), its application over the years in partnership with different organizations has provided ready proof of its versatility and capacity to respond to a wide range of issues associated with family farming economics: the influence of public policies on the development of agroecosystems (Rede Ater-NE 2014); a description of the heterogeneity of family farming in rural territories (ANA 2017); an evaluation of the effects of the 'Brazil Without Poverty' Program (implemented by the Brazilian Agricultural Research Corporation: EMBRAPA) and the One Million Cisterns (P1MC) and One Land Two Waters (P1+2) programs (implemented by ASA) on the economic intensity and resilience of family farming in the semi-arid region (data on evaluation of these projects are now being consolidated for publication).

In addition to the present introduction, the article contains another four sections. In the first two, the theoretical-conceptual foundations of the method are presented along with its methodological instruments. The third section summarizes some of the results of its application in a study currently being concluded on Brazil's semi-arid region. Finally, the last section lists a number of core conclusions, indicating potential future enhancements of the method.

2 – Theoretical-conceptual foundations of the method

2.1 – The dialogue between agroecology and critical economics

The method for analyzing agroecosystems proposed in this article sets out from the observation that the economic, sociological and agronomic theories underlying the agricultural modernization project largely contradict the empirical phenomena relating to the development of farming and the rural world. The failure of growth in the agribusiness economy (Delgado 2012) to result in improvements to indicators related to other dimensions of development shows the analytic and prescriptive weakness of agricultural modernization theory and recalls an emphatic statement by the economist John K. Galbraith: "Economics and larger economic and political systems cultivate their own version of truth. This last has no necessary relation to reality" (Galbraith 2004, p. x).

The objective of the method presented here is to reveal dimensions of social life and work concealed by the dominant economic theory by turning to the concepts and methodologies proposed by critical approaches to economics. Two theoretical frameworks are central to its configuration: the Chayanovian approach to the analysis of peasant economies (Thorner, Kerblay & Smith 1966; Ploeg 2013); and the social metabolism approach to the analysis of agrifood systems (Toledo & González de Molina 2007).

Ironically, both these approaches remained latent for decades in the scientific-academic world. As Sevilla Guzmán (2006) demonstrated clearly in his description of how liberal and orthodox Marxist frameworks came to dominate agrarian social thought, as well as producing 'versions of truth' that obscured important areas of reality, "wider economic and political systems" play a decisive role in obscuring theories that contribute precisely to revealing these overshadowed areas. One of these hidden dimensions is the fact that the organization of economic systems is strongly conditioned by power relations in society and not by the balancing of market prices, as postulated by economists from the neoclassical school. From this observation derives the third perspective mobilized to theoretically underpin the method: political economy, as the study of the power relations implicated in the spheres of production, transformation and circulation of values, as well as the social distribution of the wealth generated by labor.

2.1.2 – The Chayanovian approach

The seminal contribution of Russian economist Alexander Chayanov to our discernment of the singularities of the peasant economy is one of the mainstays to the method's theoretical frameworks. By describing a set of principles that control the economic functioning of family

farming units and differentiate them from the capitalist mode of production, Chayanov (1966) was able to explain why, although conditioned and influenced by the capitalist context in which they operate, they are not directly governed by market rules.

The essential aspect distinguishing peasant economic organization from its institutional surroundings is that the labor force that mobilizes the capital invested in the production unit is provided by the family itself. This means that the production unit is not structured around the aim of generating profit. Furthermore, since they are simultaneously the owners of the means of production and the workers, peasant nucleuses (families and communities) depend on the preservation – and, where possible, the expansion – of productive assets. Both factors (use of their own labor and ownership of the means of production) imply a specific rationality in the management of the resources that enable a degree of autonomy of family farming units from the service and production input markets. In this sense, the technical-economic rationality of peasant farming cannot be comprehended through the analysis of those factors conceived to determine the operation of capitalist entrepreneurial units – or, in other words, cost-benefit equations, technological standard, the availability of productive land, and the like.

Instead of the mechanistic outlook that controls the economic organization of capitalist agriculture, governed by market laws, Chayanov conceives peasant farming as an art: “We can affirm that the art of farming is rooted in the most appropriate use of the many particularities that are entailed in his farm” (Chayanov 1924: 6 apud Ploeg 2014). In this idea, Chayanov summarizes the essence of his theory: the economic organization of the family farming unit results from the constant search for adequate balances between the diverse variables involved in the reproduction of their means and ways of life. The balances between “labor and consume” and “drudgery and utility” were the two main focus areas explored in his microeconomic analysis of thousands of peasant production units in Russia at the start of the twentieth century.[7]

In summary, Chayanov convincingly showed that the peasant production unit is the material expression of strategic decisions taken by the families themselves over the course of their lifecycles. “We will fully understand the basis and nature of the peasant farm only when in our constructs we turn it from an object of observation to a subject creating its own existence, and attempt to make clear to ourselves the internal considerations and causes by which it forms its organizational production plan and carries it into effect” (Chayanov 1966 [1925]: 118).

2.1.2 – The social metabolism approach

The idea of social metabolism originally derives from Karl Marx (Foster 2005). In his conception, metabolism corresponds to the labor process through which human society transforms external nature and, in so doing, transforms its own inner nature. The effects of the labor process on inner nature condition the social relations of production. Marx postulates that "labor is first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature" (Marx 1983 [1867]: 149).

Despite the seminal character of this concept, adapted from the natural sciences to the analysis of economic systems, it remained in the shadows for many years.[8] This fertile intuition has been developed over recent decades by ecological economists, especially in the wake of Georgescu-Roegen's (1971) formulations concerning the entropic nature of conventional economic systems. According to the social metabolism approach, the relations of coproduction between society and the rest of nature are closely integrated, forming an economic-ecological system. These relations can be analyzed through the identification of five basic metabolic processes: appropriation, transformation, circulation, consumption, and excretion.

In any given socioecological system, including agroecosystems, the flows that interconnect these five processes vary over time in response to changes in ecological conditions and/or the social organization of production. By comprehending historical trajectories as a dialectical structuration between the natural and social worlds, the social metabolism approach revealed new methodological possibilities for combining the natural sciences and the social sciences (González de Molina & Toledo 2011). Among other aspects, it has contributed to an objective demonstration of the strong correlation between ecological unsustainability and social inequality in the mainstream models of development (Martinez-Alier 2009).

In order for this mutual influence between the natural and the social to be apprehend, the metabolic processes are explored through the convergence of their tangible and intangible dimensions, i.e. the biophysical materiality of flows of matter and energy, and the rules of social organization. This means that metabolic patterns are regulated by a combination of hardware and software. While the hardware operates as the material and tangible anchor point, the software corresponds to the operational programming of the metabolism, or in other words to the social configurations that shape the syntax of the economic-ecological flows (González de Molina & Toledo 2011). The social metabolism is thus decisively conditioned by institutionally-regulated mechanisms of social integration.

Defined as the rules of the game in a society (North 1990), institutions correspond to the intangible dimension of the social metabolism. For this reason, economic-ecological analysis requires the adoption of an institutionalist approach to economic activity. Polanyi (2012), one of the classic authors of the institutional economy, identified three predominant mechanisms in the organization of economic systems:[9] reciprocity, redistribution and market exchange.

Reciprocity is the mechanism by which economic flows are established between symmetrical individuals and/or groups. It thus amounts to an economic system rooted in networks of proximity[110] that establish their own mechanisms for regulating flows of exchange. Redistribution implies that economic flows travel from the actors embedded in the economic system to a central nucleus before then returning to the actors according to rules implemented by the central nucleus. The tax system is the main organizer of the flows centralizing a portion of social wealth, which is subsequently channeled by redistributive flows enabled by the mediation of public policies. Market exchange is the mechanism by which economic flows are freely established between social actors according to their own interests. In this case, the functioning of the economic system depends on the presence of an institution regulating exchange through the use of measures of equivalence of value universally recognized and accepted by the social actors integrated in this system. The institution is the price-setting market, while the measure of equivalence is the currency.

Central to Polanyi's analysis is the fact that the combined functioning of these three forms of social integration depends on the presence of well-established institutional structures. From this perspective, economies can be classified according to the dominant forms of social integration (K. Polanyi 2000).[111] As we shall see later on, this approach is central to the theoretical grounding of the analysis of the 'degrees of commoditization' of agroecosystems proposed by the present method.

2.1.3 – Political economy and the centrality of labor in social reproduction

According to Marx (1983), the scientific discovery that the products of labor, like value, express the human labor consumed in their production marked a revolutionary turning point in the history of economic thought and the development of humankind. He emphasized, however, that this discovery did not dispel the fantasy responsible for assimilating the social character of labor and the value generated by it with the intrinsic nature of things, as though commodities have their own existence independent of human labor.

This fantasy was enshrined by the neoclassical school of economics at the end of the nineteenth century, in a historical context marked by the expansion of capitalism. It was in this environment that neoclassicists contested the labor theory of value and formulated an alternative theory of utility value as the basis of the economic system. This strand of economic thought conceives the economy as a system of exchanges of commodities, whose value depends not on labor but on individual interests expressed in the relations of sale and purchase in the market place. As a consequence, markets assume the central role in the economic system as an aggregate of the individual choices of economic agents who seek to meet their different needs through them. In sum, for neoclassicists, only utility is a generator of value, expressed in the commodities that thereby take on their life as autonomous entities without origin and without history.

By concealing the central place occupied by labor in economic processes, the logical exercise of neoclassical economics, greased by a strong mathematical apparatus, performs the role of legitimizing the power relations and distributive systems that sustain capitalism and the market relations in which socially generated value is transformed into money.

This commodity fetishism that conceals the social relations responsible for the production of value in things also hides the relations established with nature during the labor process. In the same way that human labor is exploited and concealed in the inert and objectified form of the commodity, nature too is subjected to a process of objectification and uncontrolled exploitation by an economic system whose physical center of production and distribution is controlled by an intangible, abstract and infinite form of embodying value: capital.

The more distant and less transparent the relations between human labor, nature and the goods produced by it become, so the more pronounced and more effective is the concealment of labor-value in social relations and the perceptions of economic dynamics in contrast to the central role attributed to markets.

With the advent and dissemination of the technological packages of agricultural modernization and the gradual configuration of agrifood systems into the format of vertical chains, this concealment effect slowly but insidiously penetrated the universe of family farming. At least three forms of representing the economy of agroecosystems have contributed to this process of alienation: a) economic analyses focused on products or production chains render invisible the complex and diversified labor process undertaken to optimize added value through productive diversification and cost reduction strategies; b) economic evaluations conceive agricultural products as natural goods, ignoring the fact that they contain value generated

through the labor of farmers; c) by limiting the concept of added value to the alteration in the form of presenting products effected by transformation, they ignore the fact that it is the new quantity of labor that adds value to the product.

As an end result of these forms of representation, the economic operation of the production unit is conceived to be the outcome of the same laws governing the market economy, combined with the biological, chemical and physical laws involved in the processes of converting inputs into outputs. Under such conditions, markets and technologies become the factors that define how, how much and in what form value is generated and distributed.

Another critical concealment effect generated by the neoclassical representation of family farming impacts on one of the central elements of the production of value and the social reproduction of families and communities: the labor performed by women in different spheres of family economic life. As well as devoting considerable time to the work directly geared towards the generation of monetary income and for the family's own consumption, domestic production comprises a central activity in women's everyday lives. In addition to this work, women are also predominantly responsible for so-called 'care work,' which involves a complex interweaving of family relations and is performed in a context of irreplaceable affective and emotional relations (Castaño 1999; Carrasco 2003).

By removing the sexual division of labor from its interpretative model of economic activity, contemporary mainstream economic thought generates a profound 'conceptual silence' over the meaning and economic value of women's work and its connection to processes of wealth generation at domestic level and within society as a whole (Carrasco 1999). These prevailing analytic models – focused exclusively on market production and the conversions of values of exchange and money in markets – explicitly or implicitly locate domestic work outside the economic sphere, failing to attribute this activity any significant role and place in the production of material wealth (ibid: 18).

It is important to emphasize that this male patriarchal culture of labor also plays a decisive role in obscuring the connections and interdependencies between market labor, domestic labor and care labor, favoring the preservation of male power as the sole wealth generator, provider, and administrator of family needs.

By emphasizing the equivalent economic status of domestic and care labors, on one hand, and the labor directed towards market commercialization and family self-consumption, feminist economics has broken with many of the conceptual and interpretative models central to hegemonic economic thought. At the same time, it has worked to counteract the effects

spread by the latter at the levels of economic organization, sociopolitical relations and the ideological crystallizations dominant in our societies.

The social participation of family members is another important sphere of labor that is constitutive of economic relations yet overlooked and categorized as non-work. Social participation corresponds to the domain of sociability and the social insertion of farmers in regional-based networks and institutions through which relations of reciprocity are established, enabling the mobilization of resources unavailable in agroecosystems through a base of 'common goods' socially regulated at local/territorial level (Ostrom 2015). This base allows the creation and maintenance of the social connections essential to the technical-economic structuration of agroecosystems and to realizing the potential for optimizing added value through the labor of family members.

In sum: the focus on method proposed in this article eschews the market and the utility-value of commodities as the central axis of economic activity and restores the 'centrality of labor' in the social processes of production and reproduction. Simultaneously it breaks with the dichotomy established between the so-called spheres of productive and reproductive work, since it takes both spheres of labor to be structurally constitutive of value generation processes. Finally, by positing the equivalence in economic status of the different spheres of work in agroecosystems, it makes explicit the fact that added value expresses the necessary functional interrelations between the set of activities contributing to its generation. In line with the interpretation advanced by (Sen 2001), this focus on evaluating the dynamics of wealth production and distribution in agroecosystems recognizes farming families and their communities as centers of cooperation and conflict in the management, organization and care of life.

2.2 – The agroecosystem as the expression of a social reproduction strategy

Conceived here as a 'cultivated, socially managed ecosystem', the agroecosystem corresponds to the physical anchorage of processes of matter and energy exchanges between the natural and social spheres. According to the social metabolism perspective, it can also be defined as a 'social unit for appropriating and converting ecological goods into economic goods.' Its physical boundary is delimited by the environmental space appropriated by a 'Social Nucleus of Agroecosystem Management' (SNAM). In family farming, the SNAM tends to be the family itself. In this case, the limits of agroecosystems coincide with the boundaries of the family establishment – irrespective of the land tenure regime involved.

Areas of community use accessed for economic purposes by the SNAM are also considered structural elements of the agroecosystem. In such situations, the appropriated ecological goods originate from an environmental space whose use rules are institutionally regulated within the community as 'commons'.

When the SNAM comprises a community nucleus, as is frequently the case among indigenous peoples and traditional communities, the boundary of the agroecosystem coincides with the territory occupied by the community. In these instances, the appropriation of environmental resources by the families making up the community is basically regulated by local rules for managing commons.

Consistent with the Chayanovian approach and contrary to the theoretical perspective adopted by agricultural modernization, the SNAM are seen neither as passive recipients of changes planned by external actors – along the lines of technological diffusionism – nor as reproducers of immutable technical-economic routines established by traditional norms and conventions. Instead they are considered to be social actors who define objectives and operationalize management strategies based on a variety of interests, criteria, experiences, perspectives and opportunities.

By employing an 'actor-oriented perspective' (Long 2001), the agroecosystem can be interpreted as a management unit that contains, as a constitutive element, a cognitive nucleus with the capacity to read and interpret the conditions of the context in which it operates in order for it to shape its development trajectories in accordance with its strategic objectives.

At the same time, the approach proposed here recognizes the fact that the SNAM is not a homogenous nucleus free of conflicts of or and contradictions between its different members. In this sense, the proposed analytic approach is sensitive to gender and generational social relations, taking into account the influence of power relations within the SNAM on the overall configuration of the agroecosystem.

From this viewpoint, the agroecosystem is apprehended as the expression of a conscious strategy adopted by the SNAM to attain its economic and social objectives. Different strategies correspond to different styles of economic-ecological management and in practice are expressed through different metabolic patterns of organizing agroecosystems.

2.3 – Styles of economic-ecological management of agroecosystems

Setting out from the observation that agroecosystems are socioecological constructs that reflect the interaction between the strategic projects of the SNAM and the natural and institutional environments in which its members reproduce their means and ways of life, the

method proposed here seeks to capture the sociomaterial reality of family farming by focusing on its labor process. This end in mind, it adopts the concept of 'farming styles' as formulated and developed by Ploeg (1990, 2003, 2010).

Farming styles (or forms of practicing agriculture) apprehend agroecosystems as expressions of strategies[12] of social reproduction actively constructed and implemented over the course of the life cycle of farming families. Hence, the analysis involves three complementary points of focus:

a) an anthropological perspective that seeks to comprehend the perceptions, representations and cultural values that connect social life and the labor process under the specific material conditions in which family farmers and their communities live and produce. By adopting this approach, the analysis takes into account the fact that the organization of agroecosystems in family farming mobilizes biocultural memories and repertoires (Toledo & Barrera-Bassols 2015). Consistent with the epistemological bases of agroecology (Norgaard 1987), local knowledge and values are taken as key elements structuring the agricultural labor process;

b) a structural analysis that seeks to identify how the SNAMs interrelate with the institutional environment, looking in particular to discern the equilibrium established between non-commodity economic relations (involving reciprocity) and commodity relations. This analysis allows us to identify the effects of these relations on the economic-ecological functioning of agroecosystems, and to evaluate how and why these equilibria change over time. In essence, it is a question of analyzing the degree of commoditization of agroecosystems through an understanding distinct from the conventional structural analysis, insofar as the latter overvalues the influence of external factors in detriment to analyzing the concrete practices of the actors involved (Long 1986). An 'actor-oriented' analysis helps us to understand how farmers, men and women, individually and collectively, use their margins for maneuver to put into practice strategies that guarantee and, where possible, increase their levels of autonomy from the agroindustrial and financial sectors and from the prescriptive power of modernization policies (Long & Ploeg 1994). Maintaining, improving and protecting non-commodity relations form the core of strategies used to guarantee some degree of autonomy (or strategic distancing) from markets.

c) closely related to the previous two points, the analysis of the agricultural labor process seeks to explore the complexity involved in the labor organization strategies adopted in the SNAMs. According to Karl Marx (1983), three basic elements are involved in the labor process: the workforce; the objects of labor; and instruments. The peculiarity of the labor process in

farming is that most of its objects of labor comes from nature (animals, plants, soil, water and so on) (Ploeg 1993). As a consequence, as well as generating use and exchange values (to reproduce the workforce), agricultural labor is actively oriented towards regenerating the objects and instruments of work. For this reason, production and reproduction are dialectally structured in the agricultural labor process, forming a coherent and analytically indivisible whole.

By conceiving the agroecosystem as a unit of production and reproduction, the analysis encompasses the diverse activities undertaken in different spheres of work as a whole, one coherently structured to achieve the equally diverse economic objectives of the SNAMs. It also includes work related to the domain of 'social participation,' that is, the activities carried out in direct interaction with external institutional environments (markets, the community, political-organizational spaces, and so on). Undertaken from this perspective, the analysis foregrounds cultural, ecological, institutional and political dimensions otherwise concealed in conventional studies of agricultural development trajectories. In particular, it allows us to underline the decisive role of farmers in shaping these trajectories, confirming Chayanov's affirmation (Chayanov 1966b) that peasants are subjects who create their own existence. In this sense, contrary to structuralist interpretations of social change, the practices of the SNAMs at a micro level are not taken to be simple reactions to the development projects formulated and executed from the macro level down (Hebinck & Ploeg 1997).

The central aspect of the farming styles analytic framework adopted here is the apprehension that the agroecosystem corresponds to a unit converting resources into products and operating in dynamic interaction with the political-institutional environment in which it is immersed.

One of the striking characteristics of the agricultural modernization project is its introduction of resources mobilized in the markets in the labor process in substitution for the resources previously obtained in the agroecosystem itself or through relations of reciprocity in the community. From this point of view, "farming styles […] can be regarded as ever so many responses to the modernization project. […] Some styles primarily represent the internalization of the modernization project (and are materially dependent on its continuation). Other styles, on the other hand, represent a distantiation from, and a deconstruction of the all-embracing and overpowering modernization project" (Ploeg 2003: 113).

Distinct farming styles emerge precisely from the different responses of farmers living and working in the same territorial context to changes in the local political-institutional

environment. These responses are strongly influenced by moral economies (Scott 1976) that condition the forms in which the farmers perceive, interpret and respond to real life situations.

As social constructs culturally rooted in specific historical-geographic contexts, styles can be understood as territorially referenced sociotechnical networks since they encompass social and material elements (including natural) and above all the interrelations between the two (Ploeg 2003).

This analytic framework has proven extremely useful in terms of describing the diversity of family farming (Niederle 2006). On one hand, it helps us move beyond the generalizations of conventional appraisals and official statistics, which conceal the specificities related to the reproduction strategies of rural families and communities. On the other, it avoids particularist analytic approaches that ultimately identify each individual agroecosystem as the expression of a specific logic of production.

The typology of agroecosystems formulated in the farming styles framework is not designed to pigeonhole rural establishments into watertight categories, like the official schemas adopted to guide the allocation of public resources. The empirical reality of agroecosystems is much more complex than the binary representations employed in the institutionally enshrined classificatory schemas. Although the styles are expressed materially through technical and social practices, the same practices may be employed in agroecosystems managed according to distinct styles. Hence what defines a style of management is not the adoption of a specific practice, or a defined set of practices, in the labor process, but how they are interconnected in space and time in a form consistent with the strategic approach of the SNAM.

One decisive factor in the analytic distinction between different styles is the relative importance assumed by market relations in the organization of the labor process of the SNAMs. This 'degree of commoditization' of agroecosystems reflects the balance between the resources mobilized in the markets and the resources reproduced in the agroecosystem itself and/or mobilized in the community through relations of reciprocity. From the viewpoint of the approach adopted here, therefore, a specific style of economic-ecological management of agroecosystems translates as a particular equilibrium of the relations established between the agroecosystem, on one hand, and the community, markets and the State, on the other. This entails that instead of using binary logics to categorize agroecosystems, the approach makes use of a diffuse logic mapping varying degrees of commoditization.

In this sense, farming styles can be understood as particular forms of structuring the labor process in SNAMs. In other words, they reflect patterns of coherence between the activities

realized in the different spheres of work and correspond to specific logics used in the economic-ecological reproduction of agroecosystems.

2.4 – Levels of peasantness

The trajectories of agricultural modernization promote styles of economic-ecological management that entail a continuous externalization of reproduction-related activities in agroecosystems. An increasing number of activities are thus effectively separated from the labor process, performed by outside economic agents instead.

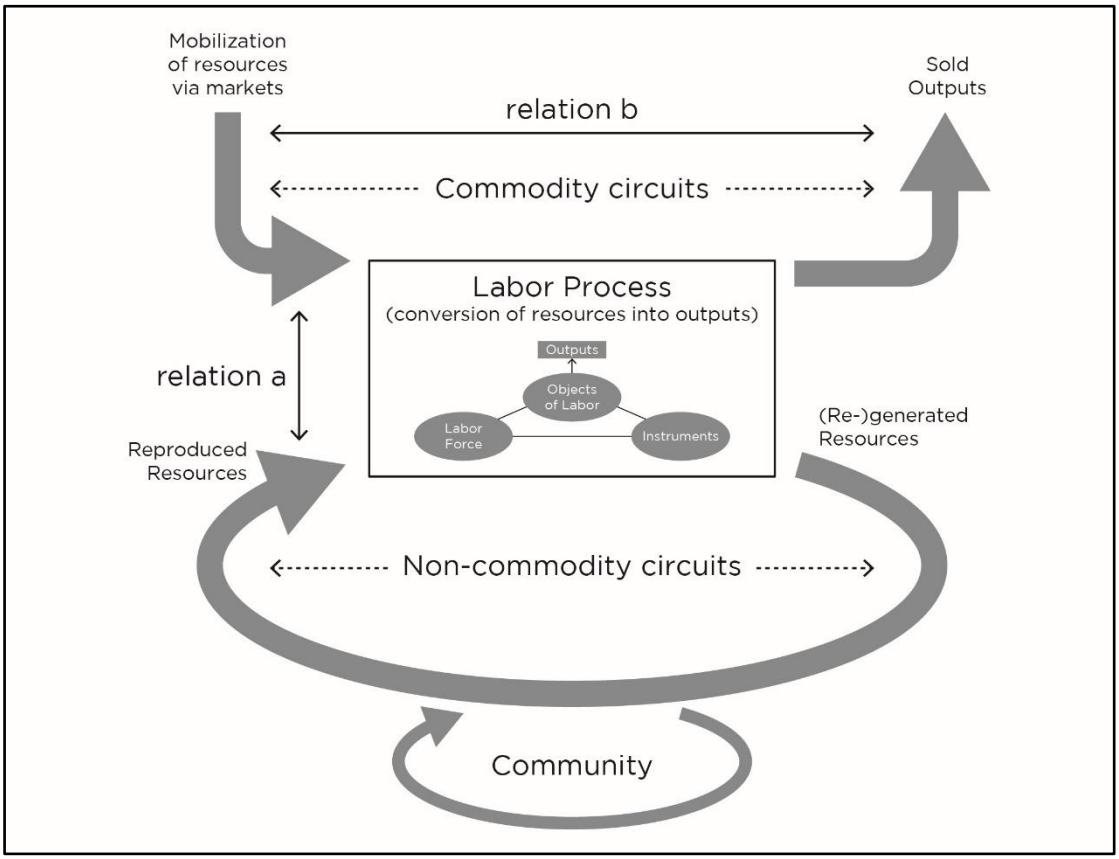
The configuration of agroecosystems according to contrasting styles can lead to two polar patterns of reproduction: "relatively autonomous, historically guaranteed reproduction"; 'market-dependent reproduction' (Ploeg 1993). The former correspond to the peasant mode of production and the latter to the entrepreneurial mode of production (Ploeg 2009).[13] The major contribution made by the farming styles analytic framework resides in the fact that, in real life situations, these two modes of production cannot be discerned as watertight categories, which establish the division of the rural social world in a dualist form between 'peasants and entrepreneurs'.[14] Consistent with the diffuse logic used to interpret the diversity of economic-ecological management strategies employed in family farming, agroecosystems should be analyzed according to their 'levels of peasantness', as proposed by Woortmann (1990) from an anthropological perspective and Toledo (1999) from the perspective of ecological economics.

Different levels of peasantness correspond to distinct metabolic patterns shaped by the agricultural labor process. The diagram below (Figure 1) shows two central relations in the regulation of metabolic flows in agroecosystems. The first relation corresponds to the balance between the resources mobilized via the markets and the resources reproduced by the labor process itself (relation a). The former are introduced into the agroecosystem as commodities and the latter are used without the need for market intermediation. The second relation reflects the economic-financial balance between the products sold and resources purchased (relation b). The closer to 1 this balance, the more oppressive the relation between market agents and the SNAM.

Management strategies with higher levels of peasantness combine practices that afford the SNAM greater control over the agroecosystem's set of economic-ecological flows. These practices affect all stages of the metabolism (from appropriation to excretion) and are consistently interconnected in the sense of continually constructing, enhancing and regenerating a 'self-controlled resource base'.

This resource base is composed of elements from the natural and social spheres. From the natural sphere, the SNAM seeks to quantitatively expand and qualitatively improve the management of ecological assets mobilized in the labor process (land, water and genetic resources). From the social sphere, it seeks to ensure the control, improvement and reproduction of devices of collective action that allow an amplification of the workforce in quantitative and qualitative terms. The coordination between the natural and social spheres in a metabolic pattern grounded in the management of a self-controlled resource base is founded on technical and social interactions centered on the valorization and continual expansion of ecological capital and social capital.[15] These strategies require a large investment in reproductive labor, a qualified work par excellence, since they are oriented towards the precise concatenation of multiple operational tasks in time and space.

Figure 1: Metabolic flows in the agroecosystem (Ploeg 2008)



In technical-economic strategies more closely focused on commodity exchanges, financial capital assumes a central role in shaping economic-ecological flows. In order to render these strategies viable, production is primarily oriented towards generating products with an

exchange value, which are converted into money in the market. Under such conditions, reproductive work loses some of its relevance, leading the agroecosystem's operational tasks to become increasingly externalized and inducing the operational simplification of the labor process.

2.5 – Contrasting development trajectories of agroecosystems

The analysis of agroecosystems from an actor-oriented perspective emphasizes the need to contextualize the system within a historical trajectory shaped by the strategic decisions defined and redefined by the SNAM over time. Consequently, the configuration of the agroecosystem at any particular moment can be seen to correspond to a contingent point in a development trajectory that materially expresses the interface between the accumulation of strategic decisions taken in the past and the actions of the present informed by prospects for the future.

Considering that the economic-ecological reproduction style adopted by an SNAM guides the course of its actions over time, the development trajectories of agroecosystems subject to the same structural conditions can evolve in fairly contrasting directions.

From a strictly economic point of view, the development trajectories of agroecosystems can be interpreted from two analytic perspectives: as variations in 'scale' and as variations in 'intensity.' Scale corresponds to the number of objects of labor per workforce unit employed in the conversion of these objects into products (i.e. into use and exchange values). The number of hectares, animals or fruit trees managed per worker (or by hours worked) are indicators of the scale of production. In this sense, the objective of any increase in scale is to boost labor productivity, i.e. the coefficient of the "income/number of workers" ratio in the agroecosystem concerned.

Intensity refers to the production (or the value of the production) obtained per object of labor. In farming, intensification signifies an increase in technical efficiency in the work of converting ecological goods into economic goods. Production per cultivated hectare, per head of cattle bred, per fruit tree managed are all indicators of intensity.

Patterns of development based on increases in scale and intensification are not mutually exclusive in either time or space. They can succeed each other at different moments of the agroecosystem's trajectory or may be simultaneously combined in the logic of managing the subsystems forming the agroecosystem. Alternation in these patterns over time basically stems from transformations in the circumstantial conditions faced by the SNAMs during their life cycles as they seek to achieve their economic objectives.

The availability of land (and other ecological goods) and labor force at different moments of the agroecosystem's trajectory are decisive variables in the definition of the development perspectives adopted by the SNAMs. These variables constitute central elements in the self-controlled resource base and can alter significantly over the life cycle of farming families. As Chayanov (Chayanov 1966b) observed, the equilibrium between hands able to do the work and mouths that are to be fed is one of the determinant factors in the economic organization of peasant farming.

The history of world agriculture can be interpreted as a history of productive intensification (Mazoyer & Roudart 2009). Boserup (1981) described this phenomenon through the study of the historical trajectories of the technological changes in farming practiced in different regions of the planet. One of the central points of her analysis is the trigger-effect played by demographic growth in local dynamics of technical and socio-institutional innovation. The innovations generated through this process provide incremental rises in the levels of physical productivity of crops and livestock herds, meeting the food demands of growing populations. One of the main conclusions of her study is that there is no agrarian ceiling or natural support capacity in any determined region. The levels of productivity obtained depend not only on ecological capital, but also on the social and human capital necessary for the continuous improvement of sociotechnical systems through local investment in experimentation and innovation.

The same phenomenon identified at macro scale by Boserup was described and analyzed by Chayanov (1966a) at micro scale, i.e. at the level of the agrosystems run by peasants. In this case, the increases in levels of consumption of family farmers during their demographic cycles also function as trigger for agricultural intensification.

The conclusions of both authors essentially highlight the relevance of the initiatives of local agents seeking to increase the efficiency of the process of converting locally available factors of production into values. In other words, they refer to "endogenous development processes" (Oostindie et al. 2008).

From the mid-twentieth century, following the imposition of the neoclassical economic perspective on the analysis and prescription of the economic operation of agroecosystems, the notion of intensification acquired new meanings, becoming associated with the employment of modern technologies recommended for increasing physical productivity as a means to obtaining adequate yields. Contrary to the approach employed in classical agronomy (i d'Abadal 2002), the trajectories of intensification began to be comprehended and represented

thereafter as exogenous development processes – or, in other words, processes dependent on continuous inputs of external resources obtained from markets.

This new form of comprehension introduced a significant incongruence between the currently enshrined notion of land productivity and the formal meaning of intensity as a reference to technical-economic efficiency. An eloquent demonstration of this incongruence relates to the controversy notion of 'sustainable intensification' that became part of the mainstream discourse in international debates on the future of agriculture and food (TRS 2009). Failing to question the technicist and productivist bias inherited from agricultural modernization, this notion reveals itself as a contradiction in terms, given that it possesses no thermodynamic basis in the sustainability of agroecosystems (González de Molina & Guzmán Casado 2017).

From the conceptual viewpoint, the intensity of an agroecosystem reflects the technical efficiency of the conversion of resources into products. This conversion occurs through the labor process, more specifically through the synergetic coordination between 'human work' and 'work of other elements of nature'. However, the conventional evaluation of land productivity hides the fact that a significant proportion of the productive resources used in industrial agriculture derives from other agroecosystems and other environmental spaces. As a result, it masks the fact that maintenance of the high levels of productivity obtained in conventional productive systems depends structurally on exogenous resources, some of which are finite and whose widescale use is responsible for a substantial percentage of atmospheric greenhouse gas emissions.[16] In this sense, when we focus on the biophysical materiality of the economic-ecological flows of agroecosystems from the social metabolism perspective, the purely rhetorical character of the new narratives legitimizing industrial farming – associated with notions of 'sustainable intensification' and 'climate smart farming' (FAO 2010) – becomes clearly evident.

2.6 – Labor-driven intensification

The term intensification can refer both to the increase in the level of intensity of the agroecosystem (or a particular subsystem) and to the process through which this increase is obtained. Contrasting styles of economic-ecological management lead to equally contrasting processes of intensification. Management styles that essentially depend on the mobilization of production factors derived from the self-controlled resource base inform labor-driven intensification trajectories. These farming styles are characterized by the higher level of peasantness. More entrepreneurial styles on the other hand – whose reproduction of the agroecosystem is market-dependent – shape intensification trajectories based on the systematic (and increasing) use of financial capital.

Ploeg (2008) argues that, despite the existence of striking historical evidence concerning the success of labor-driven intensification, this peasant-like development trajectory has seldom been explored at a theoretical level, and likewise remains absent from most current debates on development. This contradiction is mainly due to the dominance exerted by the modernization paradigm on scientific and political institutions, meaning that they have effectively been rendered incapable of identifying, describing and analyzing the possibilities of labor-driven intensification.

In the author's view, these development trajectories have been obfuscated by three types of mystifications concerning the peasant mode of production. The first relates to the supposed existence of an agrarian ceiling – that is, a support capacity inherent to the ecological qualities of particular ecosystems. According to this viewpoint, irrespective of the means at its disposal and whatever its creativity or resilience, peasant farming is also subject to a limit of economic development. As a result, it comprises a farming style condemned to the production of subsistence and poverty (Schultz 1983).

The second mystification relates to the misapplication of the law of diminishing returns, as formulated by neoclassical economics, to predicting the economic behavior of peasant farming. According to this viewpoint, above a determined level of labor investment in the agroecosystem, each additional hour worked represents a smaller increase in production, and may eventually even become counterproductive and anti-economic. In real world situations, though, this Cartesian operation of agroecosystems proves to be the exception rather than the rule. Returns do not diminish, precisely because family-run agroecosystems are dynamic, in constant evolution, with the capacity to generate adaptive responses to the internal and external transformations taking place over time.[17] Contrary to the canonical assertions about the conservative traditionalism of the peasantry found in the classic texts of agricultural modernization, longitudinal analyses of traditional communities show that creativity and innovation are structuring elements of peasant worlds.

Finally, the third mystification, directly related to the first, concerns the abundant empirical examples of stagnation and poverty among peasant communities worldwide. Through a simplistic and awkward application of the inductive method, these empirical situations of material vulnerability are presented as incontestable examples of a supposed backwardness intrinsic to peasant farming. Ploeg, however, calls attention to the fact that no complete studies exist of the specific causes of such stagnation. Furthermore, those indications already systemized – which make no connection to the alleged incapacity for development inherent to peasant farming – are systematically ignored in academic and political circles. Faced by this

scenario, the author argues that the "misery entailed in practice is turned into poverty of theory" (Ploeg 2008): 47).

'Labor-driven intensification' is basically founded on the continuous enhancement of the ecological, social and human capital mobilized in the labor process, seeking to improve the technical-economic efficiency of agroecosystems. Contrary to the logic of 'capital-driven intensification,' then, this is an endogenous approach to development, anchored in the valorization and continual expansion of the self-controlled resource base.

Following his analysis, Ploeg (2014) identifies five main mechanisms that enable this type of trajectory. These may occur in isolation or in different combinations. The first involves higher investment in the labor force and in instruments of labor. With this increased investment, the labor process in the agroecosystem is reorganized, allowing greater attention and care to be paid to each object of labor and, consequently, greater efficiency in the conversion of ecological goods into economic goods. Examples of this mechanism include more frequent and careful weeding, greater attention paid to animal health, and higher investment in labor to produce seeds, high-quality fodder, organic fertilizers and so on.

The second mechanism corresponds to fine-tuning of management practices. This is basically related to the SNAM's capacity to adapt its labor process to local ecological specificities. Contrasting with the reductionist technical strategies derived from industrial farming and designed to limit the depressive effects of critical ecological factors, fine-tuning is obtained through the use of multifunctional practices capable of regulating ecological processes at landscape scale. In other words, the aim is to develop systemic solutions to systemic problems.[18]

Fine-tuning is implemented directly by members of the SNAM based on cycles of observation, interpretation, reorganization and evaluation, very often making use of local experimentation. These fine-tuning practices are highly dependent on contextualized knowledge that can be expanded and enriched continuously through the participation of the SNAM in territorial-level sociotechnical networks where experimental knowledge circulates freely as a common good (Hess & Ostrom 2007).

The third mechanism described by Ploeg is the continuous enhancement of resources used in the production process, especially objects of labor. Generally speaking, these enhancements occur slowly through a careful balance between productive and reproductive work in the agroecosystem. Typical examples of this mechanism include improvement of soil quality (with

organic fertilizer, erosion control measures, irrigation, drainage, and so on), the genetic improvement of crop varieties and animal breeds, and the implantation of new infrastructures.

Closely connected to the previous mechanisms, the fourth is related to local innovation, i.e. to the introduction of previously unknown technologies and processes that positively alter the metabolism of agroecosystems, increasing the efficiency of the conversion of resources into products.

The fifth mechanism, decisive for the economic output of the agroecosystem, is related to what Ploeg calls a 'calculus,' i.e. the particular form in which SNAMs perceive, calculate, plan and organize the labor process. Put succinctly, it involves the contrast between the economic rationalities of capitalist and family farming. The former is interested in obtaining the maximum return on the capital invested (profit) and the latter on optimizing remuneration for its labor (added value).

Although the production of added value is the central objective of the family farming economy, different strategies can be adopted to achieve this objective. Economic-ecological management styles more closely in tune with an entrepreneurial logic (market-dependent reproduction) emphasize economies of scale, while styles with higher levels of peasantness (relatively autonomous and historically guaranteed reproduction) seek to obtain gains in intensity. In practical terms, the crucial difference between the two strategies resides in the fact that the latter emphasize the improvement in the physical outputs of their production and a reduction in production costs, while the former seek to increase the unit rentability of commercialized products (the price-cost margin) and expand the operational size of their productive activity.

2.7 – Added value: labor-generated wealth

By positing labor as a central element in the production of wealth, this method takes 'Added Value' (AV) as the central indicator in the economic-ecological analysis of agroecosystems. In this sense, the economic output of the agroecosystem is presented from a different perspective to the approach taken by official statistics and their focus on 'Gross Value of Production' (GVP). As a monetary expression of the sum of all the goods produced in a one year period, GVP masks the wealth effectively produced by the labor process, since it is calculated by combining the value of the final products with the sum of the commercial inputs used in their elaboration. AV is calculated as the difference between the monetary value of the produced goods – whether sold, self-consumed and/or given – and the costs incurred during

production. It therefore expresses the value of production without the 'double counting' effect, providing a substantive representation of the agroecosystem's economy.

The concept of added value and the interpretative models associated with it allow us to identify, typify and analyze the organization and labor processes within the SNAMs, as well as their connection to wealth generation processes. At the same time, they enable us to determine the proportional distribution of this wealth to the various members of the SNAMs (men, women and young people) and to other socioeconomic agents directly or indirectly involved in the production process (day laborers, land-lessors, banks, etc.).

Application of the concept of added value also reveals the relations of interest and correlations of power present in the dynamic organizing the economic processes in the territories in which the agroecosystems are located. It is in this sphere of circulation that the portion of wealth created through the work of the SNAMs directed towards markets is converted into a price and acquires a monetary value. Under different forms and conditions, it is in the space of the markets that the political dispute takes place for the appropriation of most of the added value produced through agricultural labor. The outcome of this dispute is essentially related to the capacity of members of the SNAMs and their level of integration with autonomous economic and political organizational processes in the territories. By incorporating these mechanisms of social participation into the analysis of agroecosystems, the SNAM ceases to be conceived as individual producers in open competition in the markets, as posited by liberal strands of economics, to be comprehended instead as socioeconomic and political actors who act in cooperation with other actors (mainly of the territory) in shaping sociotechnical networks to defend the highest monetary measure of the goods produced by their own labor.

From this point of view, by focusing on the wealth effectively generated by labor, the method proposes a double analytic approach, focusing on the labor processes that dynamize the economy of the agroecosystems, and on the nature of the individual and/or collective mediators (unions, associations, cooperatives, seed banks, etc.) and commercial circuits that provide support to the SNAM strategies for optimizing added value in the conversion of the generated wealth into money.

2.8 – Agroecology and the embedded economy of agroecosystems

Following the analytic approach proposed here, agroecosystems are understood as socioecological constructions: that is, as the result of the continuous interaction and mutual transformation between social and natural processes. The technical-economic pattern of industrial-based farming develops through the systematic attempt to disconnect the economy

of the agroecosystems from the ecology of the ecosystems on which they are structured. In such cases, the organic unity between economic production and ecological reproduction responsible for the evolution of farming practices for thousands of years is dismantled to give way to the development of industrial metabolisms shaped by linear and increasingly globalized flows of matter and energy. These metabolisms are intrinsically unsustainable: on one hand, they appropriate nature as an endless source of resources; on the other, they discard residues and pollutants back into the natural environment, treating it as a limitless waste sink.

As a scientific approach to the development of sustainable food systems (Gliessman 2015), agroecology possesses concepts and methods focused on improving and/or restoring organic metabolisms capable of promoting economic intensification without entailing the ecological simplification of the agroecosystems (Petersen, Silveira, e Galvão Freire 2012; Petersen in press). In other words, it implies a restructuring of the circularity of the economic processes in agrifood systems (Jones, Pimbert & Jiggins 2011) through the mimicking of key principles of ecological processes (Riechmann 2006), aiming to achieve the combination of different social functions of farming, starting with the production and distribution of foods in quantity, quality and diversity for a rising global population in the face of the already inexorable context of climate change and the ever more scarce source of energy from fossil fuels.

From the conceptual point of view, the issue is one of reorganizing agrifood systems through economies of scope, rather than the current trend for global expansion through economies of scale that seek to thrive through the reduction of unit costs via the productive specialization of agroecosystems and rural territories, and through the successive increase in the operational dimension of production processes. In contrast, economies of scope seek to reduce total costs through the synergy between diverse productive activities coordinated through a single management process. Economies of scope (or synergy) essentially function on the basis of the circularity of the economic-ecological flows at the level of the territories, thereby reproducing a basic principle in the functioning of natural systems: the residues of one species are used as the food of another or are converted into elements necessary to the reproduction of ecological processes at landscape scale.

The management of agrifood systems through the logic of an economy of scope is implemented via two complementary strategies: a) the utilization of the same factor of production in different productive processes, especially those over which families possess ownership and managerial autonomy, such as family labor, land and other ecological goods; b) the construction and maintenance of collective action devices at territorial level that enable families to mobilize factors of production from a resource base socially regulated within the

communities (common goods) and to economically valorize their production through local outlets, both marketable and non-marketable.

Both strategies combine to reduce the level of commoditization of agroecosystems and, consequently, to increase the levels of governance possessed by local actors over their labor processes. On the other hand, relations of reciprocity take on greater importance in the structure of governance of the metabolism of agrifood systems. Hence, the development and dissemination of economies of scope in the management of agroecosystems depends on the existence of institutional contexts favorable to the creation and stabilization of metabolic functions mediated by mechanisms of reciprocity, whether in the exchanges with nature (appropriation and excretion) or in the social sphere (transformation, circulation and consumption).

In this sense, the enhancement of the mechanisms of 'ecological reciprocity' and 'social reciprocity' is a decisive element for greater "embedded economy" (Polanyi 2000) – of agroecosystems within institutional frameworks controlled by local actors themselves, whether these are farmers, processors, merchants or consumers.

In order to apprehend agroecosystems in the context of the institutional settings in which they operate, the method proposes a set of instruments for describing and analyzing the mechanisms of economic-ecological exchange, making use of both qualitative and quantitative forms of evaluation.

3 – Methodological procedures

By taking as a reference point the theoretical-conceptual foundations presented earlier, the method combines a set of procedures for obtaining and analyzing information and data on agroecosystems. As well as determining the universe of information to be collected in the field, it proposes a specific framework to relate them coherently to the approaches advocated by ecological economics, political economy and feminist economics.

Contrary to orthodox economic theory, which approaches the social and natural worlds as mechanistic systems described and manipulated through linear[19] and politically neutral causal relations, these critical perspectives to economic science set out from the comprehension of the complexity involved in the functioning of society and nature, and, above all, of the organic and dialectic relation between social and natural processes. They also consider the influence in

power relations between social classes and between genders in the organization of labor and in the distribution of socially produced wealth.

As a result of the dynamic interaction between the social and natural worlds, the agroecosystem is apprehended as a "cultivated, socially managed." Its development in space and time results from processes of coproduction between living nature and human labor, where the latter is directly conditioned by existing social relations. In order to explore this multivariable, multi-level, multi-actor dynamic and difficult to systemize complex, the method takes as a reference point two basic ideas of systemic thought applied to ecology (Odum 1988).

a) The properties of the whole cannot be reduced to the sum of the parts. When the parts interact with each other, they generate processes of systemic self-organization (emergent properties) unforeseen by the study of the components in isolation;

b) Prior knowledge of all the parts is unnecessary for comprehension of the whole.

The combination of these two precepts in a logical process of knowledge production requires the simultaneous comprehension of the agroecosystem's structure and its economic-ecological processes. To this end, and similarly to ecology, the method elaborates models[20] as methodological instruments capable of representing the structure and functioning of agroecosystems. This simplified representation is achieved by selecting particular components and processes, making it possible to transform a generic and dispersed set of information collected in the field into a conceptual structure in which the information is condensed and coherently organized.

Partial and simplifying in nature, models are open to continual improvement and refinement. The degree of involvement is so subjective and the method so empirical that the provisional nature of the analyses made through this kind of approach is never in doubt. Adopting an approximative approach to knowledge building,[21] the method is based on the principle of optimal ignorance, i.e. focused on the objective of collecting the information necessary and sufficient to acquire increasing levels of comprehension of the dynamics of the analyzed agroecosystems.

By creating a common basis for dialogue, the modelling tools proposed here enable the perceptions and interpretations of different actors involved in the process – especially those of farmers (women and men, young people and adults) – to be recognized and incorporated into the analysis. The production and critical reflection on these representations in collaboration with farming families and, wherever possible, with specialists from different areas of

knowledge, are conditions for creating environments favorable to intercultural dialogue and transdisciplinarity, contributing to overcoming the diffusionist and reductionist perspectives that still dominate the methodological conceptions employed in the services of rural extension and agricultural research.

3.1 – Modelling of agroecosystems

The models for representing agroecosystems are elaborated through the organization of information collected in the field via semistructured interviews.[22] Guided by a basic script of questions spanning the universe of environmental, social, technical, cultural and institutional variables involved in the configuration of the agroecosystem, the interview is conducted in the form of a dialogue in which interviewers and interviewees have ample freedom to add aspects that they judge relevant.

The collected information relates to the structure and economic-ecological operation of the agroecosystem at the time of the interview, as well as its previous evolutionary trajectory. In order to systemize and present this information coherently, the method proposes two instruments for the modelling of agroecosystems: a timeline for organizing the information related to its evolutionary trajectory; and a flow diagram for representing its structure and functional dynamics. With the help of these instruments, the analysis of the agroecosystem is contextualized in time as a contingent point within a development trajectory, and in space as a singular operational unit linked to the social and institutional surroundings through flows of economic-ecological exchange.

3.1.1 – The timeline of the agroecosystem

The objective of the chronological record of the main events is to analyze the historical process that locates the facts in a coherent sequence. It is not, therefore, just a list of facts disconnected from each other. From this viewpoint, the systematization of a timeline is an activity essential to discerning the underlying strategies informing the evolution of the agroecosystem, highlighting the role of farmers as leading actors in their own development.

This analysis allows us to examine the present configuration of the agroecosystem as the sociomaterial expression of one among many other development possibilities contained in the past. At the same time, it helps us identify the strategic objectives of the SNAM for the future. In sum: the timeline contributes to the agroecosystem being described and analyzed as a social

construct resulting from the interface between the accumulation of technical-economic decisions taken in the past and the strategic objectives for the future.

In contrast to interpretations of agrarian realities that are based around the theory of agricultural modernization, which take rural development to be a linear trajectory driven by a supposedly superior and universal economic rationality, this analytic perspective apprehends the sociomaterial configuration of the agroecosystem as the result of historical processes shaped by strategic choices made at contingent moments of the SNAM's life trajectory. In essence, this involves a dialectical relation between the possible and the real (Kosík 2002).

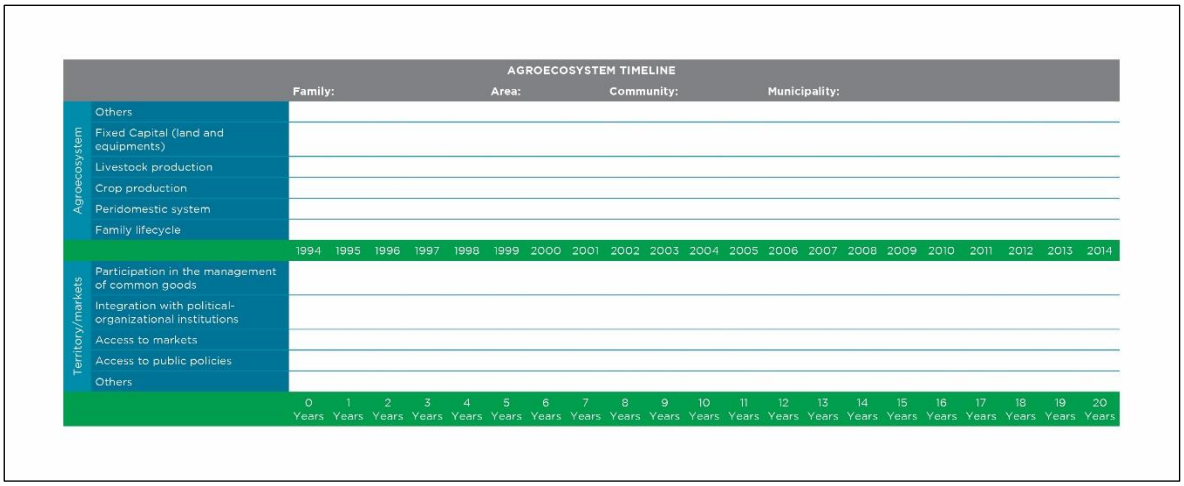
In this sense, the proposed analysis is based on a historical-dialectical materialism approach (Marx 1983), since it takes as a reference point the concrete social practices (praxis) related to the reproduction of social life, giving central significance to labor in the processes of transforming nature and mediating social relations. By adopting this analytic perspective, it becomes possible to observe how the practices adopted over time by the SNAM mutually interact to shape a particular sociotechnical system, while also being coherently linked to sociotechnical networks structured at wider geographic scales.

In apprehending the agroecosystem as a sociotechnical system shaped by the SNAM's reproduction strategy, the proposed analysis focuses attention on the patterns of congruence between the technical-economic practices adopted over its evolutionary trajectory. These patterns simultaneously define the internal organization of the agroecosystem and the external relations established by the SNAM – that is, the different levels of integration with and/or strategic distancing from sociotechnical networks structured in the territory. These patterns of congruence are actively constructed by the SNAM based on the selection of practices at each moment of the trajectory in response to both positive and negative contingencies inside and outside the agroecosystem. In sum, the focus is simultaneously on a pattern of organization of the labor process that guides capital investments, and on the interlinking of the different productive and reproductive activities that strongly influence the agroecosystem's trajectory of innovation. Although there are no determinist rules in these evolutionary processes, different patterns of sociotechnical organization tend to stimulate contrasting trajectories, providing a sense of continuity between the past, the present and the future in the process of agroecosystem development.

The essential information on the agroecosystem's trajectory is recorded in a matrix specifically formulated for this systematization (Figure 2). As well as organizing the most significant facts according to a logic predetermined by variables both internal and external to the

agroecosystem, facilitating the comprehension between them, this instrument seeks to standardize the systematization procedure, facilitating the communication of its contents.

Figure 2: Spreadsheet for recording information on the agroecosystem's trajectory



The information recorded on the timeline can be interpreted in two complementary directions:

a) Longitudinally, by interpreting the information over the years, changes can be identified in the trajectory. Generally speaking, the agroecosystems evolve through subtle changes, the outcome of a gradual incorporation of economic, socio-organizational and technical innovations. Over time, these changes significantly alter the structure and functioning of agroecosystems. In other situations, trajectories can be observed to undergo abrupt changes (positive or negative) at specific moments, leading to a rapid reorganization of the SNAM's labor process. These critical moments of change usually occur when the SNAM increases its access to land (through purchase or distribution policies), gains access to new markets, begins a new economic activity, or loses a family member (through death or migration), when drastic changes occur in the environment and/or markets, and so on.

b) Transversally, the analysis seeks to determine the mutual influence between the different variables recorded on the timeline and their effects on the evolutionary processes of the agroecosystem. In essence, it aims to identify how, at each moment of the trajectory, the SNAMs recombine the elements of the labor process (objects of labor, workforce and instruments) and respond to changes in the political-institutional

surroundings. Two key elements can be identified in this exercise: a) the influence of the mechanisms for the SNAM's social integration into the community and markets on the labor process (including production and processing techniques, commercialization channels, access to knowledge and common goods, etc.; and b) the influence of public policies on the processes of transforming the agroecosystem's structure and functioning.

3.1.2 – Representation of the agroecosystem's metabolism

The proposed method explores the economy of agroecosystems through a substantive evaluation of the economic process (K. Polanyi 2012),[23] seeking to analyze how the economic-ecological flows are structured and integrated in real life situations. To this end, a spatial representation of the agroecosystem is elaborated, enabling the system to be situated in relation to the metabolic processes of appropriation, circulation, transformation, consumption and excretion of economic-ecological goods. This representation is obtained with the help of flow diagrams and employs two core notions derived from systemic theory: a) the delimitation of the agroecosystem; b) the definition of the structure and function of the agroecosystem.

a) Delimitation of the agroecosystem

Any system is an abstraction. Its delimitation aims to organize and process the knowledge relating to the set of coordinated elements from the real life context that function as a structure organized in relatively autonomous form, but dependent on its surroundings to reproduce itself. In this sense, the system is a unit that reproduces itself in space and time through the dynamic balance established between the internal processes of self-organization and the ties of dependence on the external context.

The system only exists due to its double condition of openness and closure to the outside. Hence it should be simultaneously conceived as a unit belonging to the context and as a difference in relation to this context. In order to exist as part of the context, the system differs in relation to the context (Morin 2008).

As a product of particular contexts, the systems establish hierarchical levels between themselves. They are structurally subordinated in more wide-ranging systems and are composed by others located at a smaller scale. From the conceptual viewpoint, it is situated at a hierarchical level between the subsystems and suprasystems.

b) Structure and function of the agroecosystem

As well as contextual, the systemic approach is processual. This means that systems are continuously transformed through adaptive processes triggered by changes to this context. Considering its double condition of openness and closure to the context in which it is embedded, the agroecosystem should be conceived as a self-governing unit, insofar as it establishes its own limits through operations of exclusion effected within its boundaries through dynamics shaped over time as an outcome of transformations to the external and internal contexts (Maturana 1975).

This pattern of systemic organization takes the form of a metabolic network. The function of each subsystem in this network is to contribute to the production and transformation of other subsystems and, at the same time, help maintain the self-organizational dynamic of the whole. Additionally, the system selects the exchanges of matter, energy and information that it makes with the exterior in order to conserve and continuously renew its structure and functioning.

The proposed modelling instrument establishes a conceptual standardization to represent the structural elements of the agroecosystem, as well as the economic-ecological flows that link them systemically. The modelling involves three phases: the representation of the structure of the agroecosystem; the representation of the agroecosystem's functioning (definition of flows); and quantification of flows.

Representation of the agroecosystem's structure

The modelling methodology proposes the following structural units:

- Agroecosystem: corresponds to the ecological infrastructure (natural or artificial) employed by the SNAM in its labor process.

- Subsystems: defined as the basic economic-ecological management units of an agroecosystem.

- Fertility mediators: structural elements that form part of the ecological infrastructure of the agroecosystem. In the proposed methodology, just the artificial elements of the ecological infrastructure are represented, i.e. the equipment and facilities used to capture, store, transport and process the abiotic resources (water, nutrients and energy) mobilized by the agroecosystem's labor process.

- Suprasystems: corresponding to the social integration mechanisms identified by Polanyi (K. Polanyi 2000), the SNAM establishes relations with three kinds of suprasystem: the community, the markets and the State.

For the purposes of the proposed analysis, 'community' is defined here as the social universe in which the SNAM engages in economic transactions mediated by relations of reciprocity (non-monetarized exchanges).

Markets, for their part, are understood as institutions in which the products and services generated by the SNAM's labor are converted into money or, in the opposite direction, where the SNAM's financial capital is exchanged for material goods and/or services. They are represented in two distinct categories corresponding to different levels of regulation carried out by local actors: 1) socially-regulated markets and the conventional market. With this distinction, it becomes possible to discern different degrees of control exerted by the SNAM over the market transactions in which it engages.

The markets socially regulated by local actors can be comprehended as hybrid institutions, since they combine reciprocity with commercial exchanges (Sabourin 2011; Polman et al. 2010). Unlike the conventional/capitalist market, structured by abstract conventions and impersonal relations shaped by hegemonic power relations, socially-regulated markets, also called 'nested markets' (Hebinck, Ploeg, e Schneider 2015; Ploeg 2015), are structured by the direct interaction between the economic agents involved.[24] Through them are realized particular market transactions involving price formation, relations of trust and fidelity established with consumers, the quality and diversity of products and, finally, the percentage of added value retained in the territory.

The conventional market corresponds to an institution whose operational rules are controlled by outside economic agents (for instance: suppliers of industrial inputs and equipment, commercial banks, etc.). The market transactions established in the conventional market (upstream and downstream of the agroecosystem) frequently involve the outflow of a significant part of the wealth produced by the SNAM's labor process to agents outside the territory.

The economic flows between the agroecosystems and the State move in two directions: the inflows correspond to the resources mobilized through official public policies; the outflows represent tax payments.

Representation of the economic-ecological functioning of the agroecosystem

The economic-ecological functioning of the agroecosystem is represented by flows between its structural elements. The method proposes the elaboration of three specific flow diagrams based on the organization of the information collected in the field: inputs and outputs; monetary and non-monetary incomes; and the social division of labor within the SNAM.

In the first diagram, inputs are represented as inflows into the systems (in the agroecosystems or in the subsystems). The origin of the consumed inputs is essential information for the analysis. They may derive from the agroecosystem itself, either as subproducts of production processes (e.g. the use of crop remains as animal fodder or dung as organic fertilizer) or as material specifically produced to support the technical reproduction of a particular subsystem (e.g. the fodder grown in grass fields). They may also come from suprasystems, whether through market flows, or through relations of reciprocity established with other actors from the community or through public agricultural support policies. In this case the inflows come from the markets, the community or the State, respectively.

Outputs are defined here as every ecological good converted into income, whether monetary (exchange value) or non-monetary (use value). In the diagram, outputs are shown flowing directly to the SNAM (representing outputs converted into non-monetary incomes) and to the suprasystems (market, converting into monetary income, or community, converting into non-monetary income).

Income flows are represented in the second diagram. In this case, the sold production is represented by monetary income flows from the markets to the SNAMs. Non-monetary income flows from the subsystems to the SNAM (production for self-consumption) and the community (exchanges by reciprocity).

The third diagram represents the social division of labor and seeks to identify the activities performed in four social spheres: generation of agricultural income (sale, self-consumption, exchange and donations); domestic and care labor; social participation; generation of non-agricultural income (or pluriactivity).

The work carried out in the sphere of agricultural income production is represented by flows from the SNAM to the subsystems. In the domestic sphere and care work, labor is represented by circular flows within the SNAM. The work related to the sphere of social participation is represented by flows from the SNAM to the community. Finally, the work in the sphere of non-

agricultural income production (pluriactivity) is represented by flows towards the markets – even where the work is public, i.e. remunerated by the State.

As well as identifying the distribution of labor among the different spheres of occupation, this diagram represents the sexual and generational division of labor within the SNAM. This discrimination makes it possible to measure the proportional contribution of men, women, adults and young people from the SNAM to the generation of wealth produced in the agroecosystem.

The quantification of economic-ecological flows of the agroecosystem

Taking these flow diagrams as a reference point, the next stage of the modelling involves quantifying each of the represented flows (of inputs and outputs, monetary and non-monetary incomes, and labor time dedicated to different activities). The data refers to the period of one agricultural year, which corresponds to the time interval in which at least one cycle of conversion of resources into products takes place. Additionally, it comprises the period of reference for the economic accounts of the SNAMs.

Monetary and non-monetary income flows are calculated using the prior quantification of the input and output flows. This exercise enables us to evaluate the relevance of the economic-ecological flows masked by conventional economic analyses, limited to the sphere of market circulation. To this end, the method adopts the methodological strategy of measuring non-monetary income by determining the equivalent monetary value of the flows of production that are self-consumed and/or exchanged in the community through relations of reciprocity.

The quantification of the flows of labor dedicated to distinct spheres of economic occupation allows us to calculate the share of each social segment of the SNAM (men, women; youths, adults) in the joint production of the added value or the total income of the agroecosystem. The time-measuring of labor is a form of economic analysis that has been increasingly and productively adopted by feminist economics authors (Durán Heras 2010). Breaking with the dichotomy between the so-called spheres of productive and reproductive work, understood as spheres that are structurally constitutive of value generation, the methodological tool proposed for the economic analysis of agroecosystems helps evaluate the allocation of the labor force between the different social segments of the SNAMs and their communities. Among other positive effects, this analytic approach contributes to the generation of information that can support the feminist struggle against gender inequalities.

3.2 – Analysis of the agroecosystem

Taking as a reference the information and data collected in the field and organized through the use of the modelling instruments presented above, the economic-ecological analysis of the agroecosystem is undertaken from two complementary perspectives: one qualitative, the other quantitative.

3.2.1 – The qualitative analysis

Analysis of the information collected in the field tends to be a weak point in participatory rural appraisals, undermining the results and the aims of these exercises in collective knowledge building. Generally speaking, this shortcoming stems from the absence of adequate theoretical-methodological benchmarks for analyzing the complex set of variables relating to different dimensions and scales involved in the dynamics of the economic-ecological functioning of agroecosystems.

This proposal for qualitative analysis was conceived precisely to help fill this lacuna. Inspired by the concepts and instruments developed in the *Framework for Evaluating Management Systems Incorporating Sustainability Indicators* (MESMIS, in its Spanish acronym: Masera, Astier & López-Ridaura 2000),[25] it adopts a conceptual framework based on systemic theory applied to agroecology, helping guide participatory processes of critical reflection on different qualities of agroecosystems.

Despite its qualitative nature and the presence of a subjective component to its evaluations, the method makes use of a rigorous logic for organizing and translating the information and data collected in the semistructured interviews in synthetic indicators that condense the meanings of various consistently and mutually interconnected parameters, reflecting different systemic qualities.

The analysis of the agroecosystems in the territorial context in which they are embedded is a determinant aspect of the method. By identifying the links established with sociotechnical networks at territorial level, the agroecosystem can be comprehended as a system institutionally rooted in hybrid economic relations combining market exchanges and reciprocity. Hence, as well as considering the perspectives of different actors involved in the analysis, the evaluations only acquire meaning when contextualized in the real life situation of the territories in which the agroecosystems are materially and institutionally embedded. This relativist perspective (Laudan 1990), founded on a participatory and contextual analytic

approach, also distinguishes the proposed method from conventional approaches, based on positivist, absolute and universal premises.[26]

Systemic attributes: the focal points of the qualitative analysis

The functional organization of socioecological systems, including agroecosystems, stems from the non-linear dynamics between ecological, economic, social, political, technical and cultural variables. According to systems theory, these interactions generate emergent qualities (or emergent properties) which singularize the system in relation to the context in which it is embedded.

As discussed earlier, the agroecosystem's patterns of organization are the result of strategies of economic-ecological reproduction (or management styles) implemented by the SNAMs. As a consequence, in a given territorial context, the emergent qualities vary significantly between the agroecosystems.

The proposed method guides analytic reasoning in the sense of translating the objective information collected in the field into synthetic judgements on specific qualities of the agroecosystem, apprehended here as 'systemic attributes.' The following attributes are examined in the analysis: a) autonomy; b) responsiveness; c) social participation of the SNAM; d) gender equity/women's protagonism; 5) young people's protagonism.[27]

a) Autonomy

Following Ploeg's proposition (1993), the strategies of economic-ecological reproduction observed in agroecosystems can be described according to two polar patterns: 'relatively autonomous and historically guaranteed reproduction' and 'market-dependent reproduction'. In the empirical reality of family farming, the autonomous agroecosystem, completely free of social overdeterminations, and the captive agroecosystem, subject to all the external political-economic demands and determinant factors, constitute theoretical opposites encountered only in exceptional situations. Hence the autonomy of the agroecosystem will always be partial, more or less accentuated as a consequence of the restrictions and opportunities encountered in the external context and the strategic options adopted internally by the SNAMs.

Furthermore, autonomy is not a static condition over time. It varies as a result of circumstantial or permanent transformations in the political-institutional, economic and environmental environment in which the agroecosystem operates and as an outcome of the

strategic decisions taken by the SNAM itself. Consequently, the level of autonomy is always contingent and the result of dynamic balances established between the external determinants and internal capacities for response.

As an attribute resulting from the balance between the conditions inside and outside the agroecosystem, autonomy should be evaluated from a double perspective:

- As the SNAM's room for maneuver (or margin of freedom) to implement reproduction strategies consistent with its economic perspectives and life projects. In this case, the attribute refers to the internal conditions and should be stated as 'autonomy for...'

- As a power relation established between the SNAM and the social and political universe constituted by agents and institutions that determine and regulate the rules for appropriating natural goods and the economic-ecological flows within agrifood systems. In this case, the attribute refers to the relations with external actors and should be stated as 'autonomy from...'

Autonomy can only be fully apprehended when observed from both sides. For the first perspective (*autonomy for...*), autonomy is increased with the expansion of the 'self-controlled resource base' through which the SNAM mobilizes production factors without the need to resort to market purchases. On the other hand, a limited and under pressure resource base implies lower levels of autonomy.

This analytic perspective is congruent with the notion of 'development as freedom,' as formulated by Sen (2001). According to the latter's approach, development occurs when individuals and collectivities control the 'means' by which they can achieve their desired 'ends.' In the author's words, "[...] development consists of the removal of various types of unfreedoms that leave people with little choice and little opportunity of exercising their reasoned agency" (ibid: xii). For this actor-oriented perspective, the results of development are reflected not only in improvements to material life but also in the capacities of farmers (individually and collectively) to define and put into practice their reproduction strategies.

Adopting Sen's analytic approach, these capacities are conditioned by three elementary factors: the 'stock of resources' accessed by the labor process; the 'possibilities for production' linked to the technological pattern and the mastery of knowledge; and the 'exchange conditions' related to the power exerted over market transactions.

Economic-ecological management strategies founded on the construction, maintenance and, where possible, continuous expansion of a self-controlled resource base are characterized by high levels of investment in qualified reproductive work, designed to interact the multiple tasks undertaken in the SNAM's various spheres of work.

Meanwhile the second analytic approach to autonomy (autonomy from...) indicates that this attribute is higher when the 'level of externalization' of the operations linked to the SNAM's labor process is lower – i.e. there is a lower transfer of control over productive resources to outside actors (banks, companies, cooperatives, technical specialists and industries). An increase in levels of externalization implies a larger proportion of resources entering the production process in the form of commodities, progressively destructuring the agroecosystem's organic unity between production and reproduction, making the SNAM more structurally dependent on market relations and the technical and administrative requirements associated with them (Ploeg 1990).[28] In this sense, this second approach to evaluating autonomy is directly associated with the agroecosystem's 'level of commoditization.'

In more autonomous agroecosystems, markets are utilized mainly as routes for selling production. In less autonomous (or more dependent) agroecosystems, markets act as an organizing principle of the labor process. Adopting this perspective, the resulting gradation can be associated with the agroecosystem's levels of peasantness, the most autonomous being those identified with the peasant mode of production and the least autonomous those more closely identified with the entrepreneurial mode of production.

By highlighting the central role of the SNAM's labor process, analysis of the autonomy of the agroecosystem focuses attention on the decisive element in the economic-ecological reproduction strategies of farming families: namely, the production and appropriation of the highest added value possible vis-à-vis the agroecosystem's objective internal circumstances (autonomy for...) and external circumstances (autonomy from...).

A set of objectively verifiable parameters is associated with the SNAM's capacity to economically optimize its workforce, whether to amplify added value, or to limit transfer of this value to external agents.[29] Mirroring the two approaches to analyzing autonomy, this set of parameters is subdivided into two groups. The first is related to the use of marketable productive resources and corresponds to autonomy from the inputs and services markets. The second group is related to the self-controlled resource base (these parameters are presented in the next section).

b) Responsiveness

Responsiveness is an attribute related to the capacity to respond to changes in the social, economic and environmental surroundings of the agroecosystem. These changes may be positive or negative – in other words, they may restrict or create new opportunities for the development of agroecosystems.

The construction of higher levels of responsiveness involves the continuous investment of the SNAM over the years with the aim of enhancing internal mechanisms for systemic self-regulation, providing greater assurance that it can achieve its economic and social objectives. Hence, the development of responsiveness results from the adoption of conscious strategies by the SNAM to counter its perceptions of risk. In this sense, responsiveness is a quality actively constructed through the combination of strategic decisions of a preventive kind and tactical movements of an adaptive kind. For this reason, agroecosystems managed with the objective of maximizing short-term economic gains tend to present lower levels of responsiveness.

Responsiveness can be analyzed from four complementary perspectives, each of which corresponds to a type of response to changes in the socioecological context involving different levels of intensity and predictability. These are: stability, flexibility, resistance and resilience.

- Stability: the agroecosystem's capacity to maintain or raise production levels in response to recurrent and predictable fluctuations in the context. Responses to this kind of fluctuation do not require structural alterations in the agroecosystem since it possesses internal compensation mechanisms capable of dealing with such fluctuations.

- Flexibility: the agroecosystem's capacity to adapt when it is confronted with unforeseen and permanent changes to the context. Adaptive changes imply the need for structural transformations in the agroecosystem to establish a dynamic of systemic self-organization adapted to the new context. More flexible agroecosystems adapt to changes in context more quickly and with lower costs.

- Resistance: the agroecosystem's capacity to maintain its dynamic equilibrium when faced with intense unforeseen and episodic (transient) changes to the context in which it operates. More resistant agroecosystems remain active during periods of disturbance. In general, responses related to this resistance are associated with the presence of internal compensation mechanisms and with the stock of resources available to the agroecosystem during the period in which the disturbance is manifested.

- Resilience: the agroecosystem's capacity to recover its dynamic equilibrium after reducing its activity in response to intense unforeseen and episodic changes to the context in which it operates. The quicker and more autonomous this capacity for recovery, the higher the agroecosystem's resilience.

c) Social participation

Social participation is comprehended here as the set of non-commoditized relations established by the SNAM within the socio-institutional environment in which it lives and produces. Although an equally determinant factor in evaluating the agroecosystem's autonomy and responsiveness, it is analyzed separately in order to increase the visibility of the economic exchanges based on reciprocity, a mechanism of social integration decisive to the reproduction of family farming (Sabourin 2011).

The different practices of social participation contribute to the formation, consolidation and stabilization of mechanisms of collective action at territorial level. The active participation of members of the SNAM in community life is an indispensable condition for common goods to be created, accessed and mobilized for the labor process. This is why this method counts the time of social participation as reproductive work. Analytically-speaking, social participation can be interpreted as a strategy for expanding the physical and social limits from which the SNAM mobilizes the elements of the labor process (objects of labor, labor force – including the associated knowledge – and instruments) for the economic-ecological reproduction of the agroecosystem.

Access to resources redistributed by the State is also strongly influenced by the practices of social participation of the SNAM, in particular participation in spaces of collective deliberation and influence over the processes of elaborating and executing public policies (unions, associations, cooperatives, etc.).

d) Gender equity/women's protagonism

The focus on the analytic parameters of this attribute help shed light on gender-based social relations in the context of the SNAM, making visible various forms of oppression practiced against women that are frequently overlooked in conventional analyses of family farming economies. By analyzing this parameter and integrating it with the others, the method contributes to the production of information that can lend support to women's struggle against patriarchy, in particular to the systemization of a set of empirical evidence important

to the denaturalization and political challenging of traditional practices surrounding the sexual division of labor and other asymmetries in the power relations between men and women.

e) Young people's protagonism

Expanding the range of possibilities for young people from the SNAM to work, acquire professional training and realize their life projects (inside or outside farming) is one of the key objectives of the processes designed to stimulate the material and symbolic transformation of family farming. Recognizing rural youths as people with rights and increasing their access to alternative forms of work, income, educational spaces and leisure in the rural world are essential conditions for overcoming the intergenerational asymmetries and conflicts related to the agroecosystem's system of management, frequently controlled by the figure of the father as head of the family. These culturally-rooted asymmetries tend to be accentuated by the imposition of short-term productivist perspectives on the logic of economic management of agroecosystems. By analyzing the intergenerational relations in the SNAM, the method seeks to increase the visibility of this central dimension of the long-term prospects for the continuity of family farming.

Evaluation of the systemic attributes

Evaluation of the systemic attributes involves interpreting all the information collected in the field and systemized with the help of the models designed to represent the agroecosystem, as presented earlier. Although it is not essential to evaluate all the proposed systemic attributes, the analysis of the whole provides a broader vision of the current dynamic functioning of the agroecosystem and its prospects for sustainability. On the other hand, the method is open to the inclusion of other attributes, enabling particular aspects not contemplated in this methodological proposal to be evaluated.

Each attribute involves the integration of a narrow set of objective parameters that, in turn, are specified by associated criteria. Consequently, the method makes use of a logical framework composed of criteria, parameters and attributes that guide analytic reasoning, allowing the information relating to the complex of variables involved in the economic-ecological functioning of the agroecosystem to be processed coherently.

In this logical process, the criteria operate as conceptual devices for selecting and interpreting the relevant information concerning each of the evaluated parameters. The interpretation of the criteria related to each of the parameters is translated into scores on a scale of 1 to 5 (Table 1).

The scores attributed to each of the parameters condense objective information on particular characteristics of the analyzed agroecosystem. The advantage of this representation using combined valuations is that it simplifies communication of a complex and interdependent set of variables, facilitating the comparative evaluation of the agroecosystems in time and space – that is to say, comparing different phases of their development or comparing with other agroecosystems.

Table 1 – Scores for evaluation of the parameters

Score	**Significance**
1	Very Low
2	Low
3	Middle
4	High
5	Very High

After the qualitative evaluation of each of the parameters specifying the systemic attributes, the scores are entered on an electronic spreadsheet designed to process these partial evaluations and generate combined indices (on a scale of zero to one) which express the qualitative evaluation of each of the systemic attributes, as well as the agroecosystem as a whole. As the scores are entered, the spreadsheet simultaneously produces spider graphs that visually display the qualitative evaluation of each of the systemic attributes.

Although they represent valuations comprising the average of the established scores, these combined indices provide an approximate view of the operational dynamic of the agroecosystem in relation to its surroundings. As a result, these indices are not sensitive enough to capture differences between agroecosystems managed through the same style of economic-ecological reproduction. On the other hand, significant contrasts can be identified when the comparative evaluation is made between agroecosystems managed according to different styles. As well as the synchronic comparisons (between different agroecosystems), the method enables the same agroecosystem to be contrasted at different moments of its development trajectory (diachronic comparison).[30]

3.2.2 – Quantitative analysis

The proposal for analyzing the economic performance of the agroecosystem presented here is inspired by the methodology 'Diagnostic Analysis of Agrarian Systems,' formulated as part of the Incra/FAO technical cooperation project for producing knowledge on the family farming economy in Brazil (Garcia Filho 1999). In positing labor, "a process between man and nature" (Marx 1983 [1867]: 149), as the source of social wealth, the method proposes a framework of indicators that expresses the economic-ecological output of the agroecosystem from different perspectives. This operation is performed through the recording of data on the economic-ecological flows identified in the modelling of the agroecosystem into an electronic spreadsheet designed specifically to present the different indicators in a numerical and graphic format.

Once the raw data has added to the spreadsheet, the indicators are presented at different levels of aggregation, generating a detailed representation of the economy of the agroecosystems broken down into different analytic areas: by subsystem, by sphere of work (commercial and self-consumption, domestic and care work, social participation and pluriactivity), by sphere of economic circulation (commercial exchanges or reciprocity), by gender and by generation.

By diversifying the perspectives of conventional economic analysis, the generated indicators reveal labor and power relations concealed in the official statistics on agriculture and agrifood systems. This diversification of the analytic viewpoints is provided by generating a series of indicators including:

- Gross Income (GI): composed of values corresponding to the sum of the sold produce and the self-consumed and donated produce. This means that in effect it is constituted by a monetary portion and a non-monetary portion.

- Added Value (AV): equivalent to the Gross Income minus the costs related to intermediary consumption (IC), i.e. the market-purchased inputs that are entirely consumed in the production process. This indicator expresses the wealth effectively generated by the labor process.

- Agricultural Income (AI): equivalent to the portion of Added Value that effectively remunerates the work of the SNAM. It is obtained by the deduction of the amounts spent with the payment of outsourced services. A major control over the markets of

products and the mobilization of labor by relations of reciprocity are strategies that ensure greater retention of wealth for the remuneration of labor.

- Monetary Agricultural Income (MAI): corresponds to the portion of agricultural income resulting from the sale of produce.

- Territorial Added Value (TAV): expresses the portion of wealth generated in agroecosystem (AV) that remains in the territory, generating multiplying effects on the regional economy. It is calculated by identifying the destination of the monetary resources used to purchase production inputs: whether to remunerate local actors (from the territory) or to pay companies producing inputs outside the territory.

- Rentability Index (RI): corresponds to the agricultural income recovered per unit monetary cost invested in production.

- Endogeneity Index (EI = AV/GI): expresses the portion of gross income corresponding to the wealth generated by the work executed in the management of the agroecosystem. Put otherwise, it indicates the proportion of total income generated by the conversion of ecological goods from the self-controlled resource base into economic goods. It is applied as a correction factor to conventional indices of intensity (GI/ha)(Figueiredo e Côrrea 2006)that mask the use of exogenous ecological goods in the labor process of agroecosystems.

- Intensity Level (IL): corresponds to the wealth obtained per area unit and expresses the level of technical-economic efficiency in the conversion of ecological goods from the self-controlled resource base into economic goods. It can be expressed in two forms: a) added value per area unit (AV/ha) expresses the efficiency level obtained through the activities of the labor force as a whole allocated to production activities; b) agricultural income per area unit (AI/ha) expresses the efficiency level obtained by the labor force for the generation of part of the AV directly appropriated by the SNAM.

- The Commoditization Index (CI) is equivalent to the ratio between the production costs and the total value of the resources mobilized by the labor process (including the inputs produced in the agroecosystem). It indicates the agroecosystem's degree of dependence on the inputs and services markets.

- Labor productivity is indicated by three indicators: added value per hour worked (AV/HW); agricultural income per hour worked (AI/HW); and added value per unit of family labor (AV/UFL).

- The proportional distribution of the added value generated in agroecosystem by economic occupation, gender and generation. It indicates the proportional contribution of the different segments of the SNAM and of the labor performed in the different spheres of economic occupations to the wealth generated in the agroecosystem over a one year period.

As an aggregated representation of the agroecosystem's metabolism, the spreadsheet composes an overview diagram of the monetary equivalents to the economic-ecological flows involved in the process of converting resources into products (Figure 2).

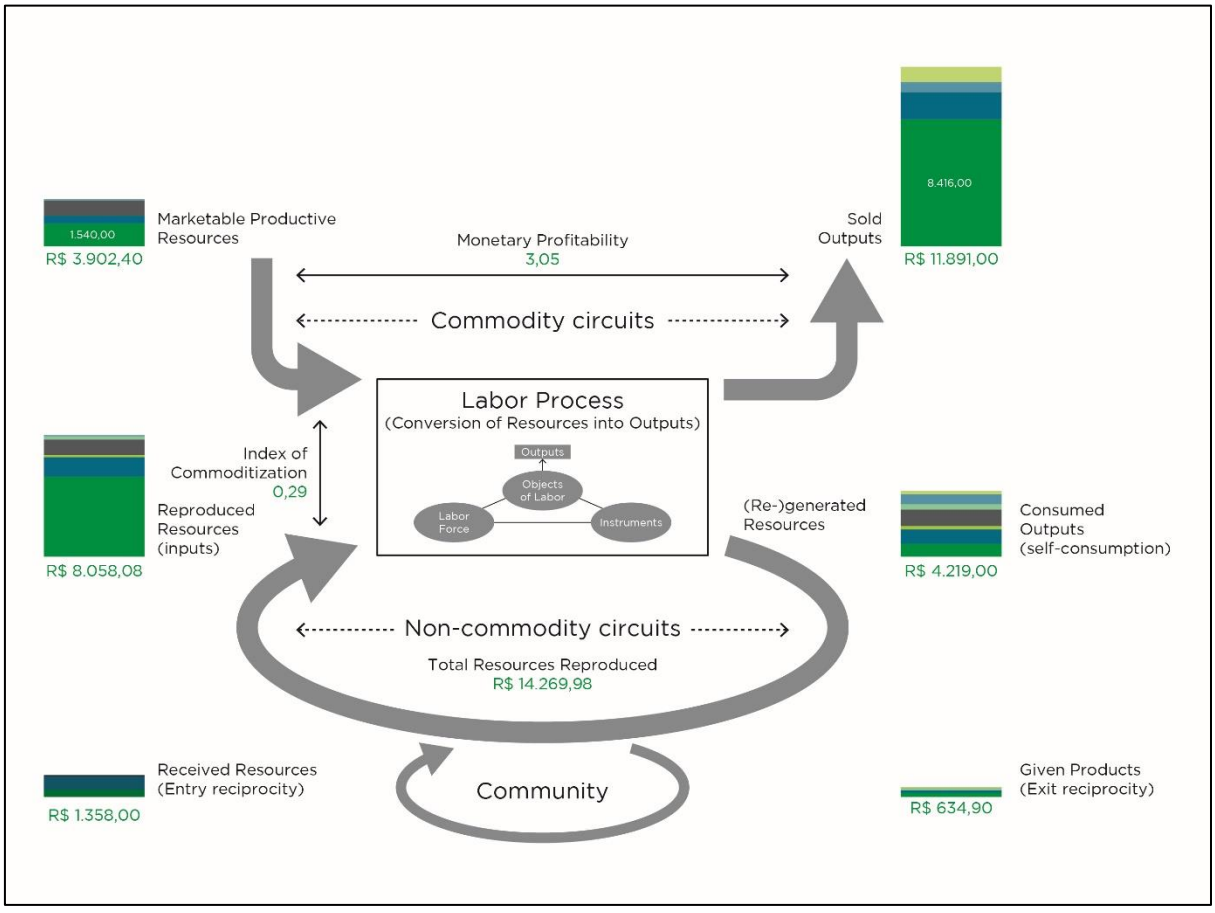
As presented in section 2.4 earlier, two economic relations represented in the diagram express the agroecosystem's logics of economic-ecological reproduction. The first concerns the balance between the revenue generated by the *sold produce* and the expenses incurred with the mobilization of production factors in the markets (marketable *production resources*). This balance, which corresponds to the monetary agricultural income (MAI), varies according to the quantity and cost of the marketable resources consumed, the technical efficiency in the conversion of resources into products, and the price of the marketed products. Monetary rentability – i.e. the percentage of remuneration from the financial capital invested in production (MAI/IC+PT) is an indicator directly derived from this balance. Although this indicator has considerable importance in defining the reproduction strategies adopted by the SNAMs, it assumes a central role in the agroecosystems employing entrepreneurial styles of management, since its economic-ecological flows are essentially governed by the 'market logic.'

The second relation corresponds to the balance between marketable production resources and the resources reproduced through the labor process in the agroecosystem and/or received from third parties through relations of reciprocity. In management styles with a higher level of peasantness, a relatively higher percentage of resources mobilized for the labor process comes from the self-controlled resource base, implying a higher degree of autonomy from the inputs and services markets. The relative degree of autonomy (or dependency) in relation to the markets of production factors is identified by the commoditization index (CI = PC/TPC, where PC corresponds to the costs of the resources that enter into the production process as commodities and TPC corresponds to the costs of the total production resources, that is, the

sum of the cost of the commodities and the resources mobilized from the self-controlled resource base).

Combined, the two relations express striking differences between the styles of economic-ecological management employed by agroecosystems. In *market-dependent* styles (more entrepreneurial -oriented), the commoditization indices are higher (closer to 1), while in *relatively autonomous and historically guaranteed styles* (higher peasantness) the commoditization indices tend to be smaller (closer to 0). The progressive expansion of the self-controlled resource base (in quantitative and qualitative terms), as well as the level of technical efficiency in the conversion of resources into products, are decisive elements for the increase in rentability of the agroecosystems managed by peasant logics. In entrepreneurial styles of management, on the other hand, the levels of rentability of the agroecosystems are essentially defined by calculating the cost/benefit ratio expressed in monetary terms.

Figure 3 – Overview diagram of the agroecosystem's economic-ecological flows



4 – The method in practice

Among the various practical applications of the method described here, we present the example of the research study "Family farming systems resilient to extreme environmental events in the context of the Brazilian semi-arid region: alternatives for confronting desertification processes and climate changes."[31] Executed in partnership between the Brazilian Semi-Arid Alliance (*Articulação Semiárido Brasileiro*: ASA)[32] and the National Semi-Arid Institute (*Instituto Nacional do Semiárido*: INSA/MCTI), the aim of the research was to evaluate the effects of public programs designed to promote water security in rural communities on levels of socioecological resilience among family farming in the region.

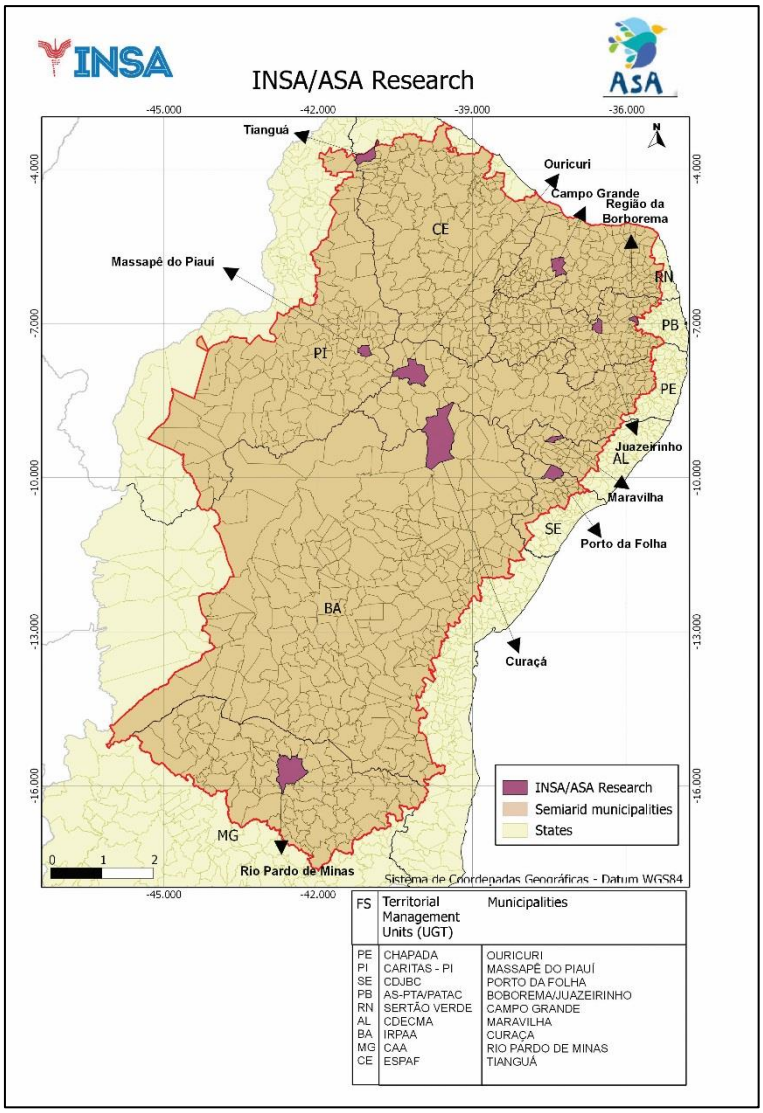
Conceived and executed by civil society organizations since the beginning of the 2000s, the programs are designed to implant small-scale water infrastructures in the rural establishments and communities of the semi-arid region with the objective of catching and storing rainwater to meet the demands of human consumption (P1MC Program) and food production (P1+2 Program).[33] As well as innovating in terms of the technological proposals for supplying water to the rural population, breaking with a historical tradition of public intervention focused exclusively on the construction of large-scale infrastructural works (reservoirs, dams, water ducts), the programs inaugurated a new approach to public action, centered on the partnership between civil society organizations and the State, aiming to promote endogenous rural development dynamics.[34] These innovations have been interpreted as a paradigmatic transition insofar as they are guided by the notion of 'living with the semi-arid region,' in a clear contrast with the 'fighting the drought' approach that historically informed State initiatives in the region (Silva 2006; Conti & Pontel 2013).

More than 15 years after the start of the programs, more than 1.1 million cisterns ('first water') were constructed, the majority part of the P1MC Program, and more than 100,000 water infrastructures ('second water') by the P1+2 Program (MDSA 2016). Despite the existence of empirical evidence of the positive effects of the programs on the material life of the region's rural families and communities,[35] a systematic study encompassing different socioenvironmental contexts has yet to be undertaken.

The INSA-ASA research study sought precisely to fill this lacuna in order to systemize useful learnings for improving public policies both for adapting to climate change and for combating desertification in the Brazilian semi-arid region. It was conducted amid a lengthy period of drought which tested the socioecological resilience of the agroecosystems in the region.[36]

Setting out from the premise that resilience should be understood as an emergent property resulting from the dynamic interaction between social and ecological variables, the study sought to describe and analyze the effects of the structural and functional transformations occurring in agroecosystems located in different states of the semi-arid region after the involvement of their SNAMs in ASA's programs. As well as incorporating water infrastructures as 'fertility mediators' in the metabolism of the agroecosystems, this involvement included the participation in farmer-to-farmer exchanges and capacity training courses organized by the programs. Figure 4 identifies the locations where the research was conducted.

Figure 4: Geographic location of the 10 rural territories where the study was undertaken and the local organizations responsible



The hypothesis tested was that the ASA programs exert a 'trigger-effect' on the sociotechnical innovation trajectories in family farming in the semi-arid region, simultaneously helping increase socioecological resilience through the development of mechanisms for compensating for the effects of droughts, while also increasing the levels of economic intensity and technical autonomy through an increase in the efficiency of the processes of converting production factors from the self-controlled resource base into income. Put in other terms: by influencing the main ecological constraint of the agroecosystems in the semi-arid region, water deficiency, ASA's programs contribute to expanding the 'margins of maneuver' for farming families to develop new technical-economic strategies through the recombination of locally available sociomaterial resources.

To verify this hypothesis, the research study was carried out using the theoretical-conceptual and methodological frameworks proposed by the method presented in this paper. The data and information related to the evolutionary dynamic of the agroecosystems, as well as their current configurations, were collected through semistructured interviews, systemized with the help of modelling instruments and analyzed both qualitatively and quantitatively.

Variations in the levels of resilience, autonomy and intensity of agroecosystems were ascertained through retrospective comparative evaluations that allow these systemic qualities to be compared at two moments of the agroecosystems trajectories: in the year when the interviews were conducted (between 2014 and 2016) and at the moment immediately prior to the installation of the water infrastructures by the ASA programs (data varying according to the agroecosystem). On average, the period between the two moments of evaluation under consideration spanned seven years.

4.1 – Trajectories of the agroecosystems

The analysis of the trajectories of the agroecosystems comprised a decisive stage in the process of evaluating the construction of resilience. It involved interpreting the information recorded on the agroecosystem timelines and enabled the trajectories to be comprehended as continuous processes of structuring 'webs of innovations.' This means that, during the course of the actions of the SNAMs, the first innovations created the conditions for the emergence of the subsequent innovations and so on successively.

Another aspect emphasized in the timelines is that the sequencing of innovations in time and space is a highly contextualized process in the local sociomaterial realities and evolves in response to the opportunities, constraints and strategic objectives of the families. Although

there is no predefined orientation to the innovation trajectories, many of the studies revealed that part of the stored water in the infrastructures was systemically allocated to intensifying the production of domestic yards. This option meant that these spaces acquired an importance in the economy of the agroecosystems, whether by producing a significant portion of the food consumed by the families, or by generating large volumes of products sold locally *in natura* and/or processed.

Livestock production was another important field of innovation in the agroecosystems. As well as providing larger reserves for watering livestock, the new water infrastructures contributed to the increase in the volumes of fodder biomass produced. New fodder species were introduced, including the valorization of native species, and new spaces for fodder production were structured. In many situations, the increase in livestock provided an increase in family income, as well as an increase in the volumes of manure produced. Given the heightened demand to restore fertility in new spaces of the systems (such as yards), organic fertilizer began to play an essential role in technical reproduction, ceasing to be sold in some of the studied situations. Seeking to improve the quality of the fertilizer used, other innovations were introduced, such as manure storage tanks and wormeries. In addition, cases are recorded where manure has become valorized as a source of energy production with the installation of biodigesters.

Other areas of innovation, such as the management of agrobiodiversity, replanting with multifunctional species, and local processing of produce also contribute to expanding the web of innovations in various directions and domains of work of the SNAMs. With the assistance of the flow diagrams, the changes in the metabolism of the agroecosystems can be visualized along with the increase in the density of the economic-ecological flows. Similarly to the ecological processes in ecosystems, cycles of matter and energy are produced at agricultural landscape scale, allowing the same factor of production to be used in subsequent processes of converting ecological goods into economic goods.

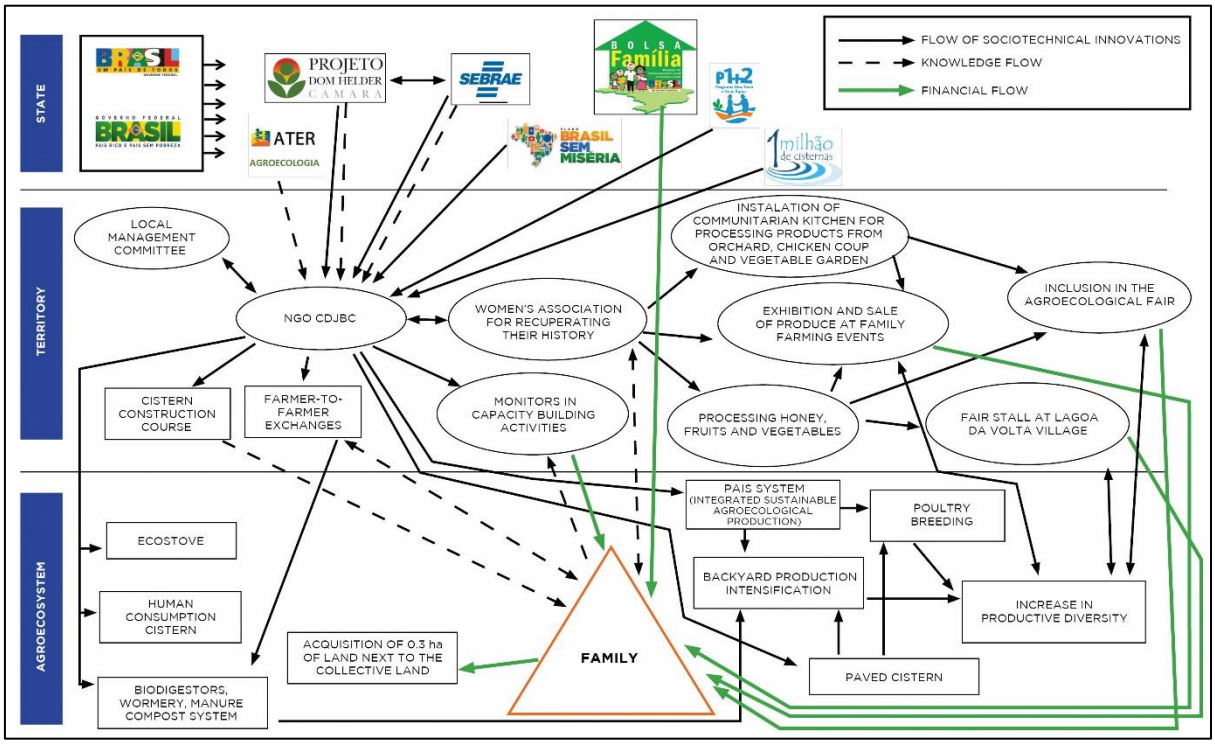
This increase in ‘connective density’ among its components and subsystems make the agroecosystem more autonomous and flexible, particularly important systemic qualities given the episodes of climate instability in the region, insofar as they contribute to expanding the range of alternatives for the allocation of locally available productive resources. Additionally, some fertility mediators function as structures for storing productive resources used during dry periods of the year or prolonged droughts, when they are not naturally available to the labor process.

One aspect that stands out in the analysis of these trajectories is that they never evolve through isolated initiatives of the farming families. Their active participation in different associative formats and local cooperation mechanisms is a decisive element for the creation of the objective conditions for changes to take place. From this perspective, the agroecosystems should be understood as structural elements of sociotechnical networks constituted at territorial level.

Another determinant factor in the evolution of these networks concerns the influx of public resources redistributed by the State. As well as the programs executed by the ASA, other government policies and programs add exogenous financial and material resources to the dynamics of local development. These resources are recombined synergetically with recourses endogenous to the territory, contributing to drive the trajectories of sociotechnical innovation.

Hence the webs of innovation should be analyzed through three levels of integration: the agroecosystem, the territory and the State. The diagram in Figure 5 shows this multi-level perspective revealing the web of innovations through the transformations occurring in one agroecosystem in the state of Sergipe following the introduction of the infrastructures enabled by ASA's programs.

Figure 5: Multi-level perspective of the web of innovations on an agroecosystem in the state of Sergipe after the incidence of ASA's programs



With the help of this schematic representation, it becomes possible to identify the dense webs established between the innovations in time and space since the installation of the water infrastructures. In the first phase, stored water enables the implantation of new economic activities and/or the productive intensification of previously existing activities. Thereafter the innovations unfold in various thematic fields, among which we can highlight the processing and commercial sale of produce, and the production and processing of inputs employed in agricultural and livestock production.

The diagram also shows that the web of innovations evolved with the acquisition of new knowledge on management practices (mainly through farmer-to-farmer exchanges) and with the intensification of the family's participation in cooperative activities undertaken at territorial level. Finally it highlights the contributions of public policies and programs to the development of the web of innovations.

It should be stressed, however, that contrasting development trajectories are frequently observed among agroecosystems located in the same territories, very often receiving support from the same public policies. These contrasts express the adoption by farming families of economic-ecological management styles that make the reproduction of the agroecosystems structurally dependent on the input and service markets. In such cases, the agroecosystem becomes linked to sociotechnical networks structured at territorial level in the form of vertical chains of specialized production. Applying the proposed method of analysis, we have shown in another paper how these contrasting trajectories generate equally contrasting effects on the dynamics of rural development (Petersen & Silveira 2017).

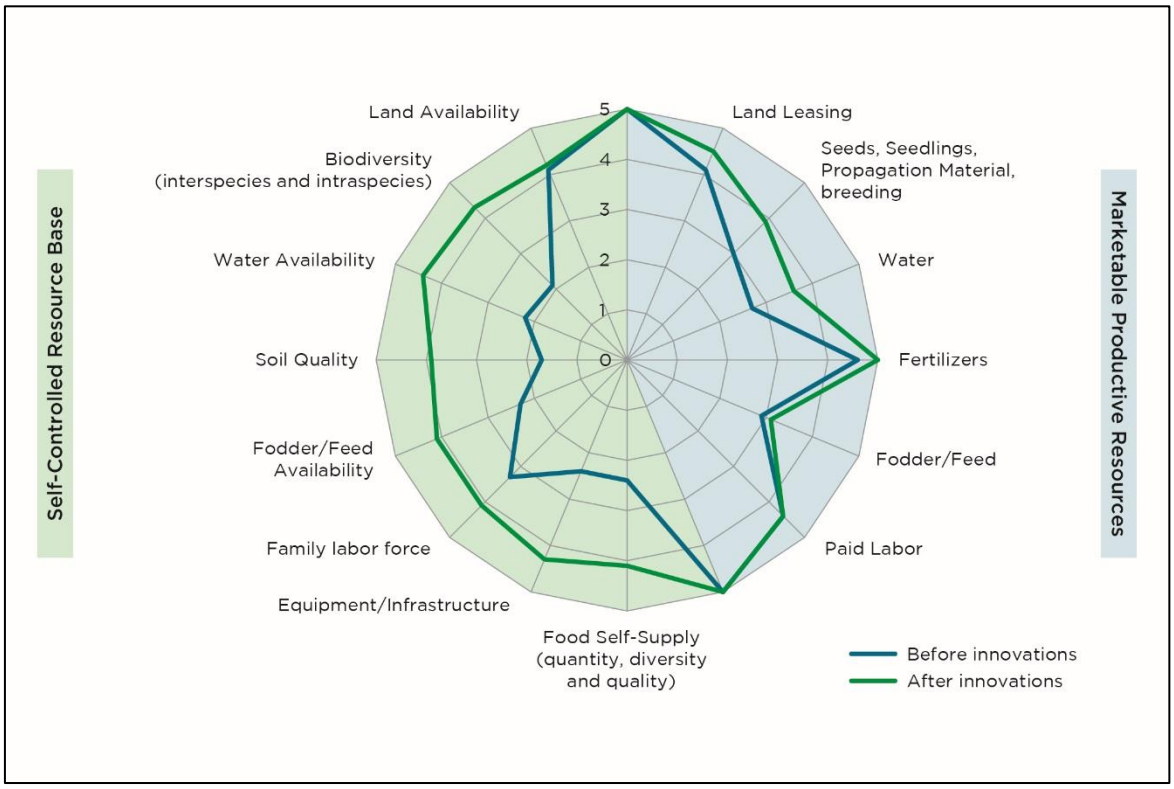
By making possible the representation and analysis of the processes of transforming agroecosystems from this systemic and multi-level perspective, the method apprehends the complex and multifaceted nature of rural development dynamics, contributing to the evaluation of its multidimensional effects.

4.2 – Effects on the autonomy and socioecological resilience of agroecosystems

Taking as a reference point the averages from the retroactive comparative analyses conducted in ten agroecosystems from different territories of the semi-arid region, the graphs reproduced in Figures 6, 7 and 8 display the effect of the webs of innovation on the autonomy and resilience of the agroecosystems.

The graph in Figure 6 represents autonomy from two complementary perspectives: a) in relation to the input and service markets; b) for the investment of the labor force in accordance with the strategic projects of the families. The first perspective corresponds to the blue section of the graph and is analyzed through the parameters associated with levels of autonomy/dependence in relation to 'marketable productive resources.' The second corresponds to the green section and is analyzed through parameters associated with different elements from the 'self-controlled resource base.'

Figure 6. Graphic representation of the average parameters related to the autonomy of ten agroecosystems from the Brazilian semiarid region at two moments of their trajectories



The aggregated evaluation of the parameters in the two sections indicates that the average index of autonomy of the agroecosystems rose from 0.60 to 0.83. Although the variation between the blue curves (before the innovations) and green curves (after the innovations) indicates the increase in autonomy in the two sections of the graph, it is notable that the most pronounced changes occurred in the section corresponding to the self-controlled resource base. This differential pattern in relation to the two approaches to analyzing autonomy is explained by the relative state of the parameters at the 'starting points' of the trajectories. While the levels of autonomy in relation to the markets were already relatively high, the

parameters related to the self-controlled resource base were initially evaluated at more reduced levels.[37]

Unlike conventional technical-economic approaches, always focused on maximizing short-term financial incomes in detriment to the autonomy from the input and service markets, the strategies adopted in the evaluated agroecosystems are characterized by combining the meeting of the immediate economic needs of the farming families with the gradual construction of a family patrimony through the systematic investment in labor inside and outside the establishments. This strategy explains the large positive variation identified in the local self-controlled resource bases, a multifaceted variation that involves tangible and intangible elements of the labor process.

From the tangible viewpoint, there are cases in which the families strove to acquire a small patch of land, using this to constitute a secure base for unleashing other transformations. In this sense, permanent and secure access to land emerges as an indispensable condition for new material investments to be made (construction of houses, water infrastructures, fences, chicken coops and pigsties, biodigesters, manure storage tanks, irrigation systems, and so on), configuring a gradual expansion of the 'agrarian capital' of the agroecosystems.

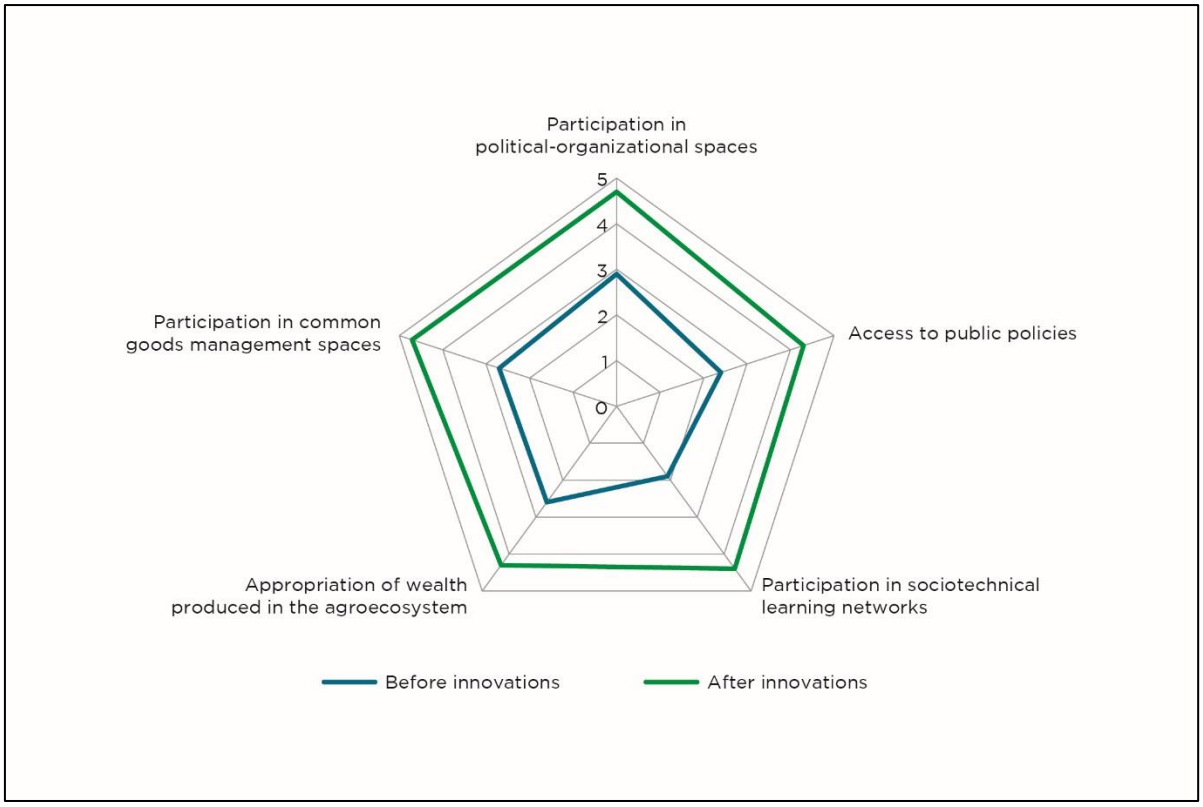
By performing the function of 'fertility mediators', the new infrastructures contribute to qualifying the labor process in the agroecosystem, particularly in the activities related to the reproduction and continuous expansion of its 'ecological capital' (soil quality, agrobiodiversity, production and qualitative transformation of biomass, stocking productive resources, etc.).

From the immaterial viewpoint, the self-controlled resource base is constituted by increasing the body of contextual knowledge related to the labor process (human capital) and by the quality and stability of relations of cooperation and mutual help established at territorial level (social capital). Through the participation in associations, unions, informal groups, seedbanks, revolving solidarity funds, local fairs and other organizational formats at territorial level, the families acquire new knowledge and end up accessing new material resources, whether they are common goods whose management is socially regulated in the community (seeds and other elements of biodiversity, community labor), or public goods, redistributed by government policies.

The variables associated with the construction of human capital and social capital are closely linked to the level of social participation of the members of the SNAM in territorially-embedded sociotechnical networks. The parameters associated with this aspect were also

evaluated in the research study and indicate an average rose in the 'social participation index' from 0.5 to 0.9. These variations can be visualized in broken down form in the graph below (Figure 7).

Figure 7. Graphic representation of the average parameters related to the social participation of ten SNAMs at two moments in the trajectories of the agroecosystems

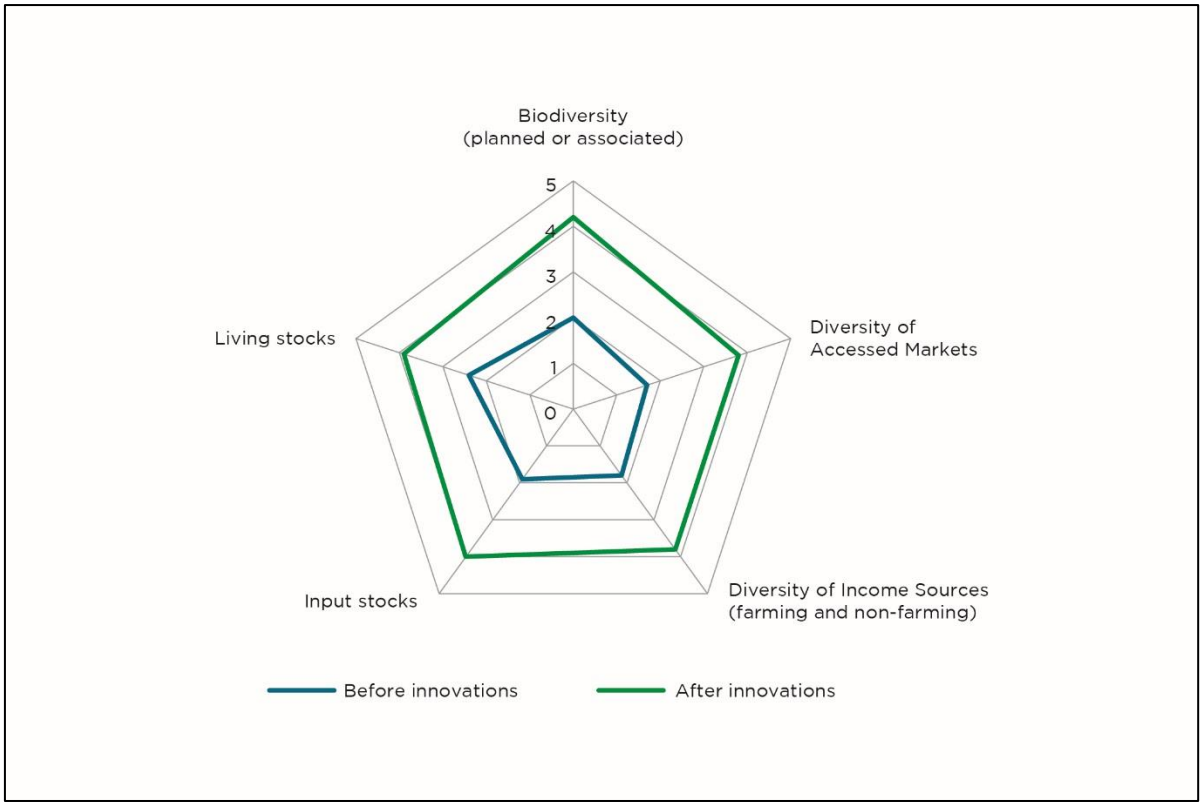


As well as influencing the levels of autonomy of the agroecosystems, the SNAM's social participation is a characteristic directly related to the levels of 'connectivity' between the agroecosystem and its socioecological surroundings, a key principle relevant to systemic resilience (Biggs et al. 2012).[38]

The proposed method indirectly evaluates the effects of the web of innovations on the levels of resilience of the agroecosystems, through the analysis of a narrow set of parameters objectively verifiable through the semistructured interviews. The development of systemic qualities associated with these parameters over the trajectory of the agroecosystems contributes to the creation and maintenance of the 'diversity of responses,' 'redundancy of functionalities'[39] and 'reserves of productive resources,' another three key principles for the resilience of socioecological systems (Walker et al. 2006).

Taking as a reference point the evaluation of the parameters related to these principles, the research study identified a significant variation in the average indicator of resilience of the ten evaluated agroecosystems: from 0.39 to 0.79 (Figure 8).

Figure 8. Graphic representation of the resilience-related parameters of ten agroecosystems at two moments of their trajectories



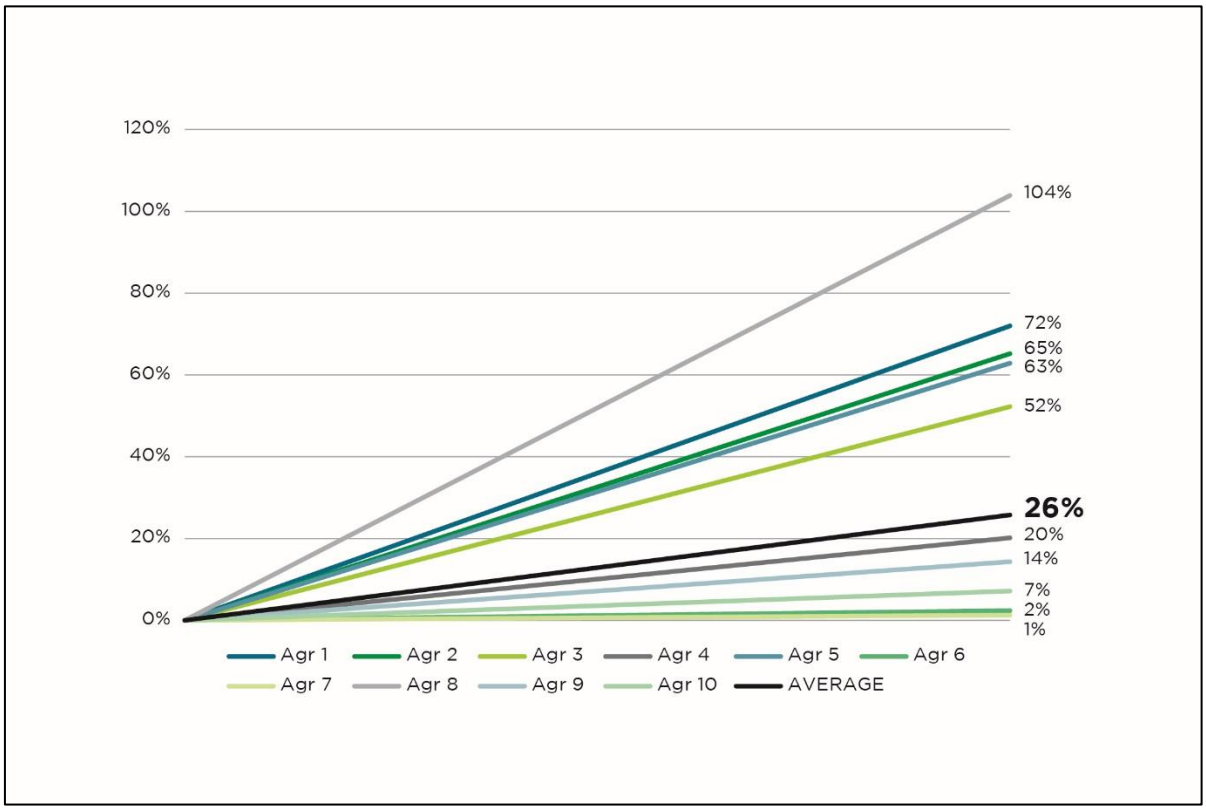
4.3 – Effects on the level of intensity of the agroecosystems

The development trajectories of the ten studied agroecosystems can be characterized as 'labor-driven intensification' processes. The increases in levels of intensity were identified through the comparative economic analysis between the moments before and after the structural and functional changes generated in the agroecosystems with the introduction of the water infrastructures. In order to realize this operation, the data related to the economic-ecological flows described in the phase of modelling the agroecosystems was quantified and processed in order to generate various economic performance indicators. Next, always in collaboration with the farming family members, the economic analysis was reworked

subtracting the data related to the flows generated following the introduction of the innovations.

Figure 9 shows the variations in the Gross Product (GP) between the two moments of the trajectory of the ten analyzed agroecosystems. Although the graph indicates the existence of a large variation between the levels of percentage increase in GP (between 1% and 104%), we can identify a general trend of economic growth with an average increase of 26% in GP.

Figure 9. Percentage increase in Gross Product (GP) of ten agroecosystems after innovation trajectories initiated with the installation of water infrastructures provided by ASA's Programs

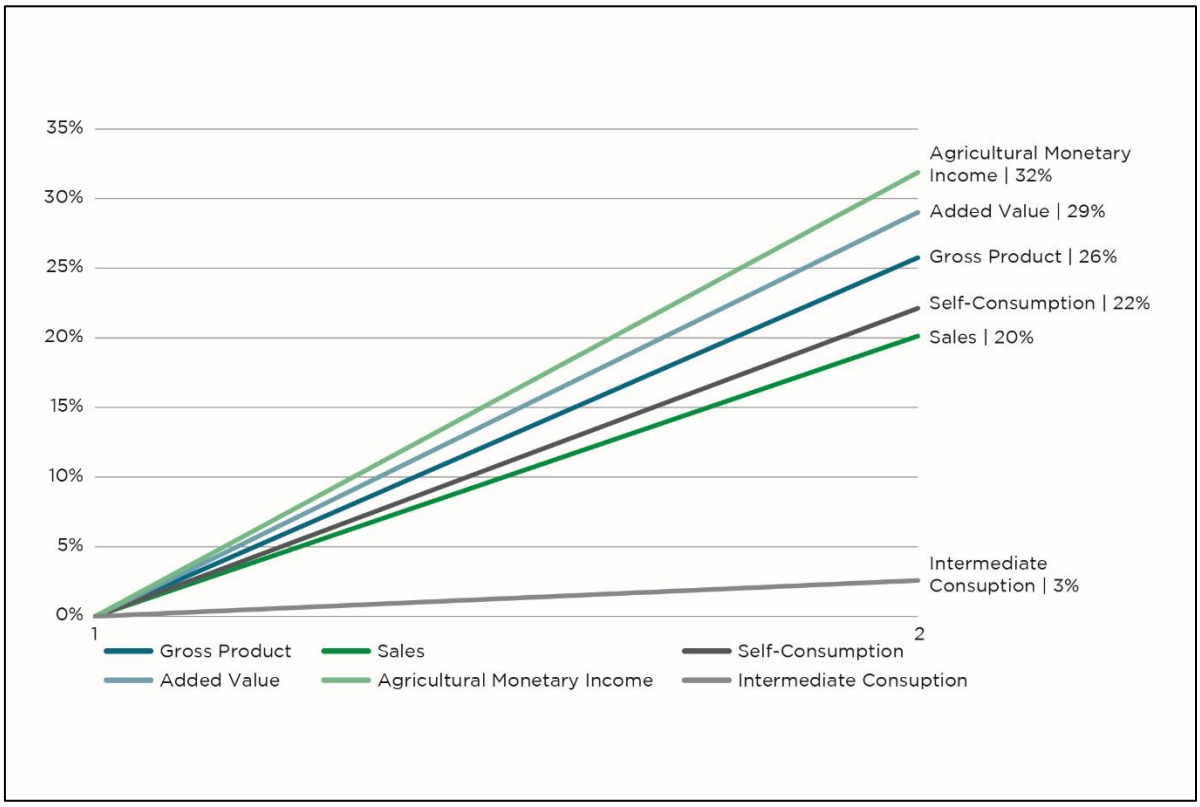


Unlike development trajectories based on productive specialization and the logic of economy of scale, the intensification trends did not affect the levels of autonomy of the agroecosystems from the input and service markets observed previously (Figure 6). This means that the variation in the GP of the agroecosystems essentially results from the increase in added value (29% on average), that is, the new wealth produced through the labor of the families. This

aspect can be seen in the graph reproduced in Figure 10 that presents the average percentage variation of the different economic indicators of the set of agroecosystems.

The average increase of 26% in the GP in response to the average increase of just 3% in the value of the intermediate consumption (CI) reflects the existence of an endogenous pattern of economic growth. This signifies a logic of reproduction of the economy of the agroecosystems rooted in the expansion of the local and self-controlled resource base by the rural families and communities. The observation of this expansion in numerical terms confirms the qualitative analysis represented in Figure 6. It comprises a process resulting from the systematic investment of labor by farmers in structuring the agroecosystems and in configuring the new relations within its socio-institutional environment.

Figure 10. Average percentage variation of different economic indicators of 10 agroecosystems after innovation trajectories initiated with the installation of water infrastructures provided by ASA's Programs



The continuous amplification of the self-controlled resource base can be understood as an increase in the capital with which the families reproduce their economies. However, the

meaning of ‘capital’ employed here corresponds to the Chayanovian approach to the analysis of the economy of family farming units, not to the classic sense defined by Karl Marx. Capital therefore refers to the family patrimony, i.e. to the means of production created and controlled by the family over the course of its life cycle. The values involved in ‘family capital’ cannot be limited to exchange values. Stocks of water, fodder, seeds and manure, for example, possess a use value since they are employed in the reproduction of the agroecosystem itself. Once used in the labor process, these values are converted into fertile soils, nurseries and healthy crops. Also mediated by the labor of the farmers, this increase in ecological capital is converted into the increase in the value of production. All these conversions essentially depend on the investment in labor and not in financial capital.

In this style of organizing labor in the agroecosystem, economic production and ecological reproduction are organically interconnected into a single process in which human labor and the work of the rest of nature are synergetically integrated, configuring a dynamic of co-production at agricultural landscape scale. In economic terms, the increase in ‘added value’ (or ‘product of labor’) over the course of the analyzed trajectories reflects the improvement of these processes of co-production. In other words, it expresses ‘labor-driven intensification.’

As well as the “reciprocity with the rest of nature,” a large investment in labor is also made to create, strengthen and reproduce collective action devices at the level of the communities and territories in which the families live and produce. On one hand, this work in the sphere of ‘social participation’ enables the mobilization of ecological assets from a base of common goods, thereby reducing the costs spent on inputs. On the other hand, this investment in cooperative activities is recompensed by the mobilization of third-party labor through relations of reciprocity, assuring a higher appropriation of the added value by farming families. Economically this aspect is reflected in the significant average increase in the agricultural incomes in the agroecosystems. These incomes, which correspond to the ‘clear part’ of the gross value of production (Zhao e Ploeg 2014), may or may not be converted in the markets. In the studied agroecosystems, the part converted into currency (monetary agricultural incomes) increased by 32% on average, while the portion consumed directly by the families (non-monetary incomes or self-consumption) increased by 22% on average.

4.4 – A substantive view of the economy of agroecosystems

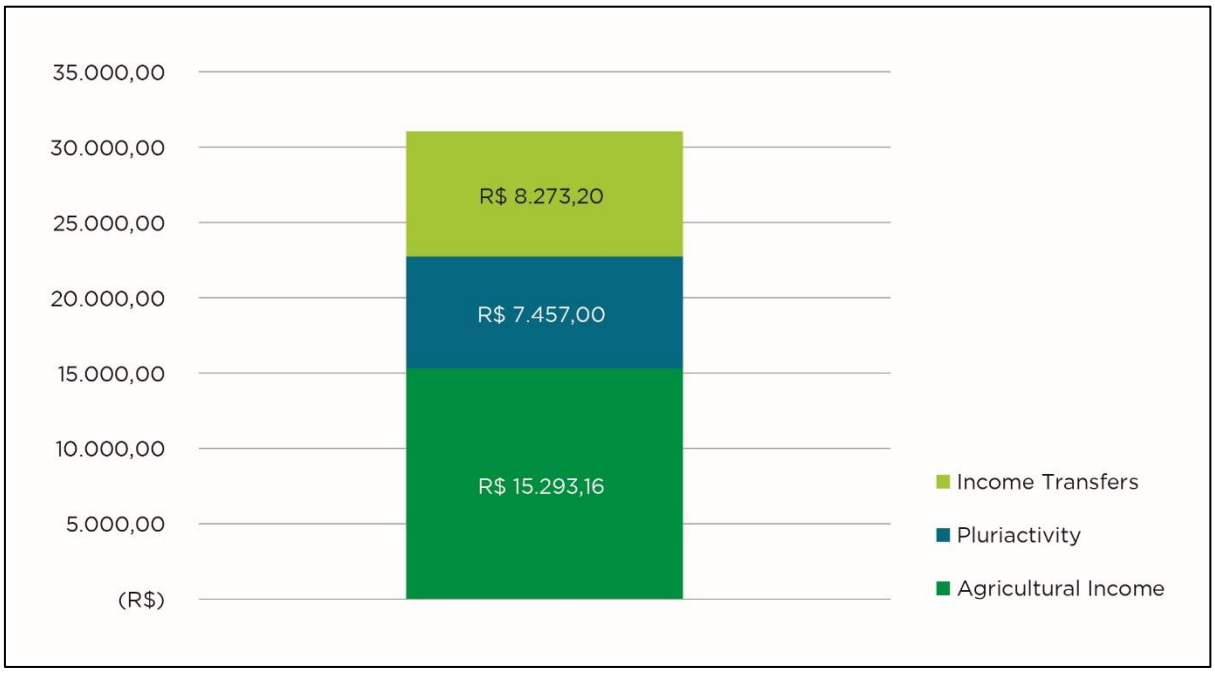
The analysis of agroecosystems proposed by the method adopts a substantive approach to the economy (Polanyi 2012). This means that the agroecosystem’s economy is comprehended as

an institutionally regulated process responsible for the generation and coordination of flows of goods and services between the domains of nature, community, markets and the State, designed to meet the tangible and intangible needs of the SNAM over the short, medium and long terms. In this sense, this process is actively commanded by the strategy put into practice by the SNAM in order to organize its labor in time and space.

Unlike conventional approaches to economic analysis, centered on subjective choices between alternative uses of scarce means, the focus on satisfying real needs allows the agroecosystem's economy to be interpreted through the different forms of allocating the labor of the SNAM among its internal sectors. Through different analytic frames relating to the origin of income and the allocation of labor times, it becomes possible to increase the visibility of social and political relations of considerable relevance to the contemporary debates on family farming's contributions to rural development and food security (HLPE 2013; FAO 2014) and, in a broader sense, to attaining the UN Sustainable Development Goals (SDGs)(UN 2015).

Among the possibilities for combined analysis of the data generated by calculating the economic-ecological flows, here we highlight three important aspects revealed by the ASA-Insa research study. The first concerns the origin of the incomes of the ten interviewed families. The graph in Figure 11 presents the total average income composition of the families, considering the inputs of agricultural income, non-agricultural income and income transfers (by public programs or by remittances from relatives).

Figure 11. Distribution of total average income of the 10 families interviewed by source



Three considerations can be made on the basis of the presented data:

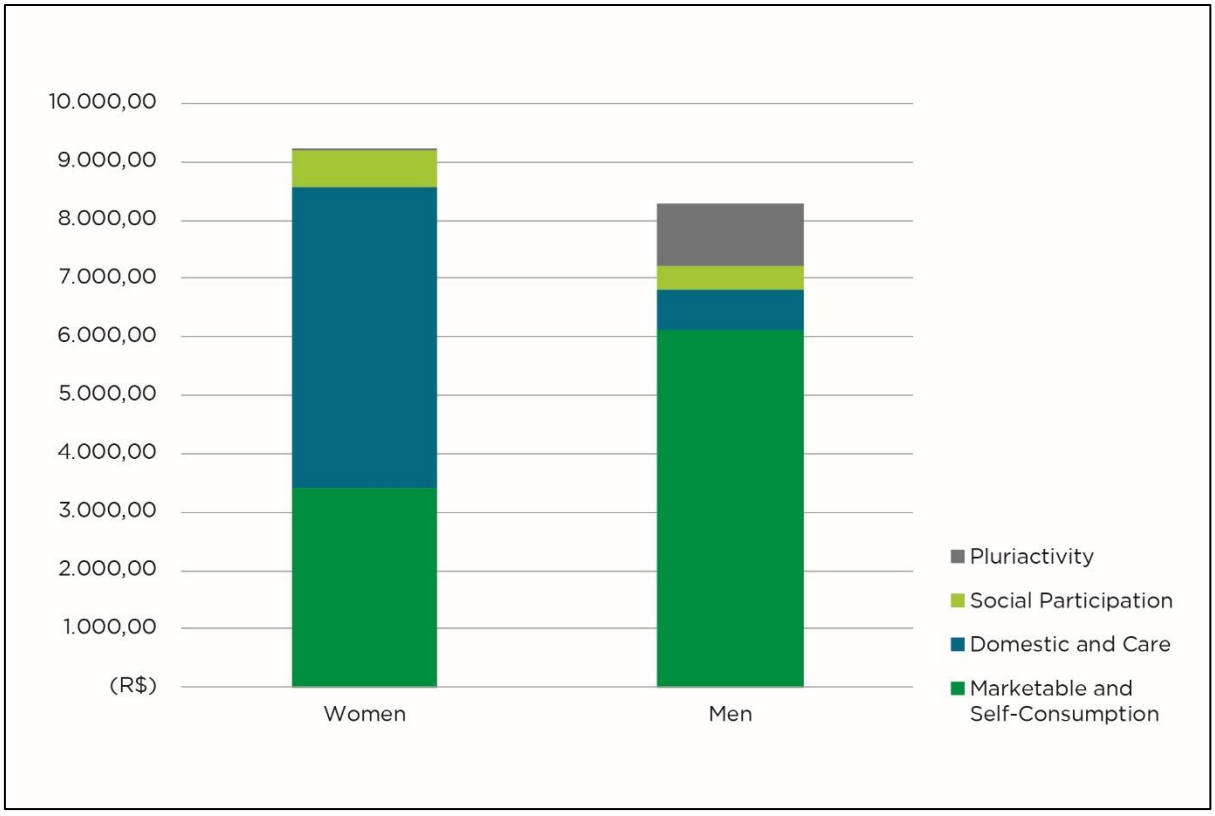
a) Half of the total income of the families came from agricultural labor. Given the fact that the data was collected in drought years when agricultural labor productivity tends to decline abruptly, we can presume that in normal climatic years the contribution (both proportional and absolute) made by agricultural income is significantly higher.
b) Pluriactivity was responsible for the generation of 23% of the families' income, confirming the fact that investment in labor for the generation of non-agricultural income is an extremely important strategy not only for the material reproduction of family farming, but also for their greater sociocultural integration in contemporary society (Carneiro 1998; Schneider 2001). Far from signaling a tendency to abandon farming and the rural world, as some authors suggest (Graziano da Silva 2002), it expresses a strategy of resistance and projection into the future based on diversifying the means of life (Niederle and Grisa 2008).
c) Income transfer corresponds to 27% of the total average income of the interviewed families. Although this proportion may vary from year to year depending on the varying levels of productive performance of agricultural activities, the resources redistributed by the State through social security and agricultural insurance policies perform polyvalent functions for the agroecosystems' economies. By reducing the levels of social vulnerability of the poorest rural families, these resources substantially increase the room for maneuver for them to invest their labor in the continual expansion of the self-controlled resource base. As well as responding to the most pressing material needs, therefore, the regular influx of financial resources contributes to structural improvements in the agroecosystems. Hence, whenever combined with multiple strategies for economic and political emancipation, the transfers effected by social policies have multiplying effects on the development of family farming.

This latter point is particularly important for farming women, since for them direct access to financial resources comprises a powerful instrument of emancipation in the face of the double condition of subalternity to which they are traditionally subjected: as poor economic agents in a structurally unequal society; and as women in a culturally patriarchal society.

The second aspect is directly related to this gender inequalities culturally rooted in family farming's forms of economic organization. By establishing an equivalence between the economic statuses of production and reproduction activities, the method allows us to ascertain the proportional contributions of men and women to the production of wealth by

the SNAMs. Based on average data from the economy of the 10 agroecosystems, the graphs reproduced in Figures 12, 13 and 14 present this proportional share of the added value from different analytic viewpoints. The graph in Figure 12 depicts, in absolute terms, the average contribution of the labor of the men and women who form the couples responsible for the family agroecosystem management nucleuses. Two main aspects can be identified in the graph: a) in absolute terms, within the couples responsible for the SNAMs, women's contribution to the generation of added value is 11% higher than that of their male partners; b) there is a large contrast between the patterns of time allocation in the different spheres of occupation according to gender. While the bulk of women's time is dedicated to activities related to 'domestic labor and care labor' (55%), most of men's time (73%) is directed towards activities of 'marketable production and self-consumption.'

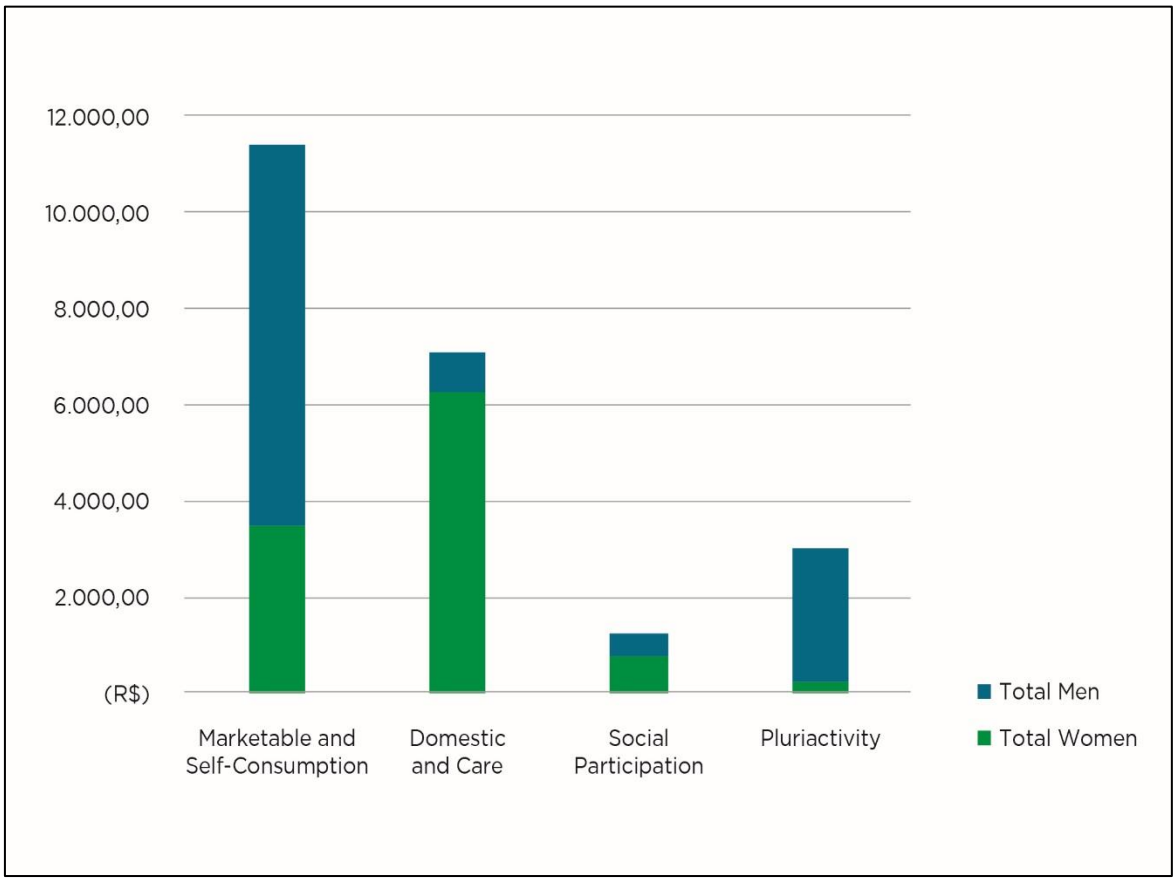
Figure 12: Average proportional contribution of men and women from the couples responsible for the SNAMs to the generation of added value according to spheres of work (R$)



This contrasting pattern in the allocation of labor time between men and women in the different spheres of work is also shown in the graph contained in Figure 13. This indicates the

times spent on labor activities of all the members of the 10 SNAMs. Two important aspects emerge in the graph data: a) 37% of the labor time of the SNAMs is allocated to activities typically considered to be reproductive (domestic labor, care labor and social participation), revealing the importance of this work in the economy of the agroecosystems; b) women assume 82% of the workload in the spheres of reproductive labor (this proportion rising to 86% when the focus is specifically the sphere of domestic and care labor).

Figure 13: Distribution of the average added value of 10 agroecosystems by labor sphere and gender

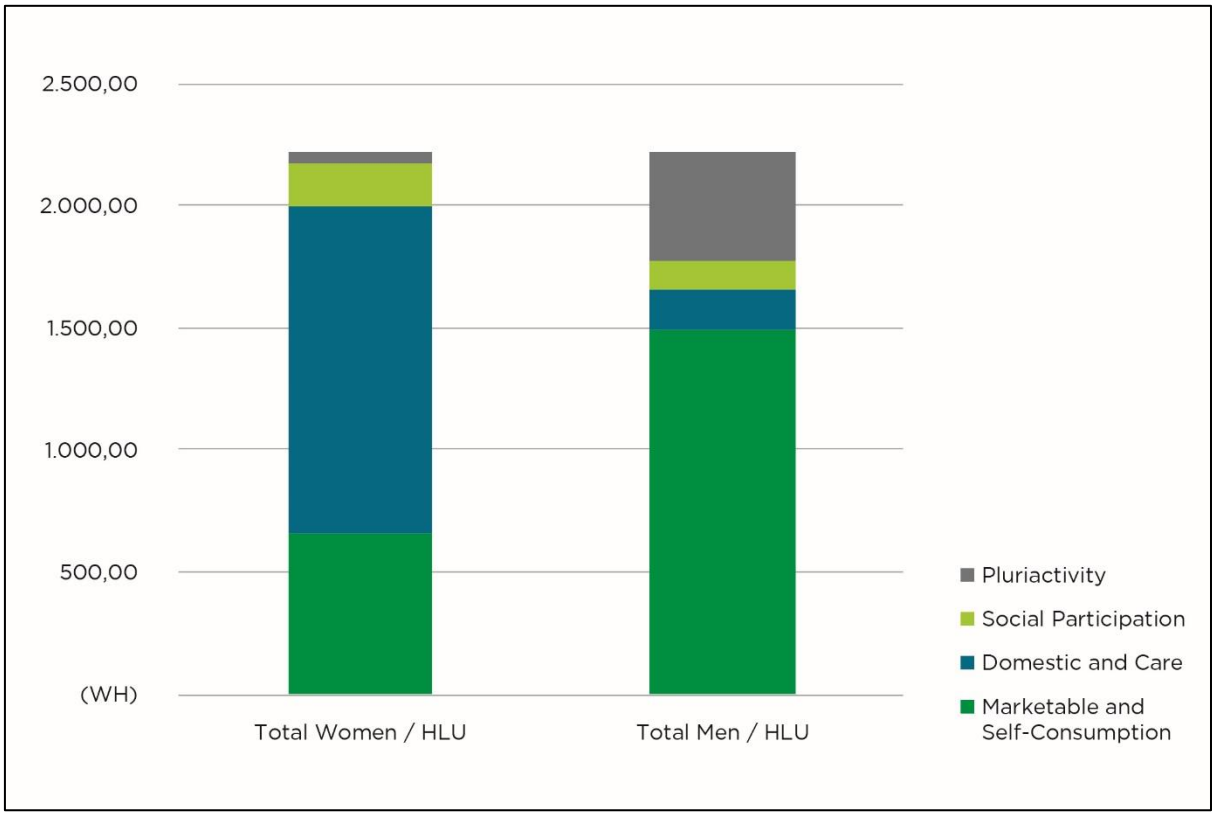


The graph shown in Figure 14 provides a more precise view of the contrast in the tasks assumed by men and women in the management of the agroecosystems. In this case, the proportions of time dedicated to distinct spheres of labor were measured by translating them into an equivalent 'hired labor unit' (HLU), that is, a period of 2105 hours per year.

The analytic focal points proposed here help shed light in the determinant role of women's labor in all spheres of work in the agroecosystem. This is an aspect overlooked by conventional

economic analyses, though it is decisive to the social reproduction of family farming. By revealing the overload of work that frequently weighs down on women and the indissociable links between the so-called spheres of productive and reproductive labor, the method produces consistent evidence to challenge culturally-entrenched ideas that relegate domestic and care activities to the category of non-work and reduce women's labor in the various spheres of marketable production to the category of help. By calling attention to these aspects, recognizing and valorizing women's varied forms of economic inclusion, the method helps uncover latent paths and potentialities for connecting the analysis of the material life of family farming to the feminist struggle for the political and economic emancipation of women.

Figure 14: Allocation of time by men and women to performing activities in the different spheres of work in 10 agroecosystems (WH)



The third aspect revealed by the research data relates to the economic output of each of the subsystems and calls attention to two features of particular importance to the family farming economy. Firstly, it shows the contributions made by each subsystem to the dynamic functioning of the agroecosystem as a whole. These contributions can be measured in exchange values (sold production) and use values (the produce consumed directly by families

and the inputs consumed in subsequent production processes). Since the conventional analytic approach takes monetary rentability as the principal indicator of technical-economic efficiency, the contributions of the subsystems to socioecological reproduction are excluded from the horizon of relevance of conventional agricultural economics. Secondly, this breakdown of the economy of the agroecosystem according to subunits of agricultural labor management allows us to discern how intensity levels vary significantly between the subsystems.

Both aspects were revealed in the analysis of the 10 analyzed agroecosystems. In the years in which the economic data was collected, although they occupy proportionally tiny portions of the surface areas of the agroecosystems, domestic yards produced, on average, 34% of the added value generated through the agricultural labor of the families. Slightly over half of this value (51%) was converted into monetary income and the remainder was consumed by the families themselves.

As well as underlining the importance of women's work in the economic output of the agroecosystems as a whole, given that, traditionally, they are the main agents responsible for the management of this subsystem, this data shows the significance of the yards in terms of building the resilience of agroecosystems, since they kept on producing during consecutive years of drought, in contrast to other subsystems which were temporarily deactivated or displayed heavily reduced economic performances.

Through its qualitative and quantitative assessments, the study confirmed the positive effects of the public programs co-managed by ASA for the resilience of family farming in Brazil's semi-arid region. Furthermore, it demonstrated that these programs helped promote rural development trajectories that reconcile the intensification of economic production with ecological reproduction. This also enabled them to reverse desertification processes under way in the region and, simultaneously, stimulate trajectories of economic emancipation for a portion of the socially most vulnerable population.

5 – Final considerations

The method presented here proposes new approaches to the analysis of agroecosystems managed by family farming. By situating agroecosystems as economic-ecological management units contextualized in specific territories, it helps shed light on social and power relations that condition the labor processes in family farming, but which are overlooked or distorted by the prevailing theories that inform the design of public programs and policies for agriculture and

for food systems. It dialogues with critical theories of economics formulated precisely to reveal dimensions of social life and work hidden by orthodox economic thought. The conceptual connections between agroecology and these critical theories are established via the following premises:

- Agroecology is a social construct driven by the convergences and disputes between economic and sociopolitical agents in defined territorial spaces. In this sense, the method dialogues with political economy, understood as the study of the power relations implicated in the spheres of production, transformation and circulation of values, as well as the social distribution of wealth generated by labor.

- The agroecosystem is a material expression of the strategies adopted by families and communities to appropriate a landscape unit in order to reproduce their means and modes of life. In this sense, the method dialogues with ecological economics, that is, with the study of the biophysical processes involved in the cycles of conversion and reconversion between ecological goods and economic goods.

- The families and communities are not homogenous social nucleuses free of conflicts of interest and internal contradictions. In this sense, the method proposes analytic concepts and instruments capable of recognizing and increasing the visibility of the labor of the different people involved in the management of agroecosystems. To this end, it adopts an analytic approach consistent with feminist economics, expressing a critical view of the sexual division of labor and patriarchy, cultural and ideological elements that structure the economic relations dominant in the domestic and public spheres and mask the essential role of female farmers in generating social wealth.

- By focusing on the agroecosystem as a socioecological construct determined by the strategic actions of a social nucleus of management, the method distances itself from the structuralist models of evaluation and planning of rural development dynamics, inflected by a determinist, linear and externalist bias to the analysis of processes of social change. In line with this critical perspective, it is inspired by the Chayanovian approach to the analysis of peasant economies. According to this approach, although the agroecosystem's economic operation is apprehended in the context of the market economy, it is not interpreted as an automatic outcome of the application of the 'general laws' of the markets. This signifies that the family managed agroecosystem is not structured according to the economic rationality of the capitalist business, since it is not founded on the capital-labor relation, as analyzed by Marx. Non-commodity economic flows and immeasurable values related to specific cultural repertoires

are decisive elements in defining the economic-ecological reproduction strategies of agroecosystems.

Setting out from the theoretical-conceptual foundations derived from these critical approaches to economics, the employment of the method has helped reveal the growing contradictions between the scientific premises of agricultural modernization and the results of its practical applications in different socioenvironmental contexts. At the same time, it has proven extremely useful in terms of supporting participatory processes of knowledge production concerning the positive multidimensional effects of agricultural development trajectories guided by the agroecological paradigm.

Applied to the analysis of agrarian realities in specific territories, the method has contributed to overcoming the normative dualist delimitations that seek to represent the complexity of the configurations in the family farming universe into watertight categories, such as 'large and small producers,' 'entrepreneurial and peasants,' 'consolidated and peripheral,' or 'agroecological and non-agroecological.' The proposed analytic approach seeks to locate the agroecosystems in the vast spectrum of features corresponding to different levels of peasantness in the economic-ecological reproduction strategies of family farming.[40]

Application of the method has also proven to be extremely useful in the evaluation of public policies. In this case, the methodological instruments for analyzing rural development dynamics emphasize the fact that the transformations in agroecosystems are strongly driven by the responses of local actors (individuals and/or collectives) to the constraints and opportunities posed by the political-institutional and ecological contexts in which they live and produce. This aspect was made explicit in the research into the effects of public programs executed by ASA on the development trajectories of family farming in ten territories from different states in the Brazilian semi-arid region.

By describing and analyzing the development trajectories of agroecosystems, the research showed how the public resources redistributed by the State through different policies and programs were decisive in terms of raising levels of economic intensity, technical autonomy and socioecological resilience in family farming. At the same time, it showed how these public resources were channeled by territorially-based sociotechnical networks in order to be combined synergetically with (ecological and social) endogenous resources, contributing to the gradual expansion of the local and self-controlled resource base by rural families and communities.

Contrasting with conventional approaches to the analysis of public policies, usually centered on ascertaining the scope of support activities,[411] the method focuses on evaluating the finalistic objectives associated with strengthening family farming's means and modes of life and the various positive effects of agroecology for society as a whole (promotion of food and nutritional sovereignty and security, generation of work and income, building socioecological resilience, conservation of agrobiodiversity, empowering women, etc.).

In summary: the method contributes to overcoming the bias of economistic productivism that prevails in conventional analyses of rural and agricultural development trajectories. Instead of the mechanistic and positivist approaches to the study of agricultural economics, the proposed analytic approach apprehend farming as the art of co-production between human beings and the rest of nature. Consequently, the subjective dimension and the approximate quality of the proposed analyses possess a necessary epistemological correspondence with the understanding that the agroecosystem corresponds to a "cultivated, socially managed ecosystem."

The current configuration of the method is the outcome of a collective construction, gradually shaped over time, based on its application to the study of different dimensions related to the socioeconomic reproduction of family farming. Like all knowledge, one of the main vocations of the proposal presented here is to be continually improved through confrontation with different realities and with other methodological approaches equally motivated by the aim of comprehending and contributing to the enhancement of the economic-ecological functioning of family farming-managed agroecosystems.

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Notes

[1] As Marx (2008) pointed out, like technologies, science should be comprehended as a productive force and conceptual language as a material force (Marx 1970 apud Moore 2015). In his analysis of the historical process, Marx demonstrated how the production of knowledge plays a determinant role in the constant renewal of capitalism's strategies of accumulation.

[2] Informed by the mechanistic paradigm, modern agronomy conceives nature as the setting for a Cartesian theatre that can be deciphered and controlled with the assistance of production functions (Ploeg 2003). Founded on the parametric method, these functions specify linear relations between the employment of varying levels of inputs and the obtainment of corresponding levels of production. In this way, they seek to define the optimal levels of input utilization, with the objective of maximizing the yield from production.

[3] Although these costs have been hidden by a dominant economic paradigm that deliberately ignores the biophysical materiality incorporated into the flows of commodities, the effects of global climate change have become apparent during the contemporary period as highly visible public symptoms of the limits of an institutional system that conceives nature as an inexhaustible source of resources and as a limitless dump for waste.

[4] Through the 'human being/nature' binarism, economics developed as a reductionist discipline (focused on the production, circulation and consumption of commodities) and a mechanistic discipline (focused on price balances in the markets), incapable of capturing the biophysical materiality and the social and political nature of economic flows, or the incommensurable values responsible for the organization of social life.

[5] A document (in Portuguese) with a more detailed presentation of the current level of sedimentation of the proposal (Petersen et al. 2017) can be found at http://aspta.org.br/2017/03/livro-metodo-de-analise-economico-ecologica-de-agroecossistemas/

[6] A AS-PTA – Agricultura Familiar e Agroecologia is a non-governmental organization that works to promote rural development and urban agriculture. As well as working via programs providing direct assistance to family farming organizations in the Northeast, Southeast and South of Brazil, it helps support the formation and coordination of civil society networks at state, regional, national and international. www.aspta.org.br

[7] For decades after the establishment of the Provincial Administration System in Russia (*Zemstra*) detailed surveys were undertaken of the peasantry, making up more than 4000 volumes in total. Based on this material, a school of agricultural economics emerged and flourished that exerted a huge influence in the country until 1920. Kossinsky and Bructus were the two theorists from this school responsible for formulating a pioneering analysis of the fundamental distinctions between peasant farming and capitalist farming. However it was Chayanov who expanded and deepened this work (Kerblay 1971).

[8] It is curious that not even Marxist economists took up Marx's fertile insight. Fischer-Kowalski (1997) trace the origin and evolution of the idea of social metabolism, presenting it as a stellar concept for undertaking economic-ecological analyses. Since then the concept has been applied to different objects of study, among which we can highlight economic development, collective health, environmental justice, agricultural sustainability and so on. Applied to the analysis of agrifood systems (González de Molina & Guzmán Casado 2006), the social metabolism perspective functions as a theoretical-methodological tool for supporting the planned transition of such systems towards more sustainable patterns of production and consumption. Given its versatility, it can be employed at various scales of analysis, spanning from a single crop area to the global agrifood system.

[9] This organization corresponds to the coordination of the movements of goods and services within society, aiming to overcome the effect of differentials of time, space and occupation. In the author's words, "thus, for example, regional differences within a territory, the time span between sowing and harvesting, or the specialization of labor is overcome by whatever movements of the respective crops, manufactures, and labor make their distribution more effective" (Polanyi 1977: 35).

[10] Proximity in the sociological rather than physical-geographic sense.

[11] In his main work, *The Great Transformation*, Polanyi (2000) interpret the historical rise of capitalism as the dominant economic system from the moment in which land and labor come to be conceived as commodities. Since then, the relative importance of the markets in the organization of social life has depended on the more or less liberal economic policies adopted by nation states.

[12] The notion of 'strategy' occupies a central position in the comprehension and analysis of agroecosystems and their development trajectories. Each strategy is closely associated with a specific logic of reproduction (Ploeg 2003) identified in terms of a 'calculus,' that is, a conceptual structure with which the farmer reads and interprets empirical reality. The author explains: "a calculus is the backbone of a particular strategy. It is the 'grammar' of the decision-making process. In entails the way in which farmers evaluate pros and cons" (ibid: 137).

[13] Mode of production, in the sense formulated by Karl Marx (1983[1867]), i.e. as the set of relations between the agents of the production and between them and nature.

[14] The term 'peasant' is not employed here to mean a social class or a political category. It refers to a *modus operandi* that specifies the labor process, directing it to reproduce patterns of socioecological metabolism that take advantage of flows of coproduction with nature, as well as relations of reciprocity in economic exchanges.

[15] The meaning of the term capital gradually widened in the social sciences in the attempt to explain differences between regions that, in principle, had the same amount of capital when measured in a conventional form. With this conceptual expansion, capital came to assume various forms: human, social, economic, cultural, symbolic and natural (Bourdieu 2011). This extension in meaning is also applied to the microeconomic analysis undertaken in the context of the agroecosystems. In this sense, capital is not limited to the classic meaning of Marxist thought. Capital in an agroecosystem is composed

of *stocks of resources*, both tangible and intangible, mobilized by the labor process. Land, equipment, infrastructures, livestock, knowledge and specific skills, networks of social relations and other resources form and shape the SNAM's tangible and intangible assets, that is, its self-controlled resource base.

[16] In order to correct this distortion, the economic accounting of agroecosystems should include the 'virtual hectares' needed for the production/extraction of the resources mobilized through the markets. As will be shown later in this paper, this method proposes the employment of a correction factor called an 'index of endogeneity' as a methodological device for amending this distortion.

[17] On this point, it is interesting to note that Lenin claimed that the law of diminishing returns is an empty abstraction that ignores the levels of technological development and the states of productive forces. "Consequently, instead of a universal law, we have an extremely relative 'law' – so relative, indeed, that it cannot be called a 'law', or even a cardinal specific feature of agriculture" (Lenin 1961: 109 apud Ploeg 2013: 107). Another remark made by the author on this theme is highly significant for the purposes of the analysis proposed in the present method: "this explains why neither Marx nor the Marxists speak of this 'law', and only representatives of bourgeois Science ... make so much noise about it" (Lenin 1961: 110 apud Ploeg 2013: 107).

[18] A typical example of this contrast concerns strategies for dealing with nitrogen depletion in cultivated soils. The practical solution to this agronomic limitation provided by the reductionist approach is the use of soluble nitrogenous fertilizers. For the systemic approach, on the other hand, the solution involves management of the biomass, including the introduction into the agroecosystem of species that fix atmospheric nitrogen. In the reductionist approach, although the limiting factor is reduced, undesired ecological effects can be generated (such as acidification of the soil, an increased vulnerability of crops to pest insects and pathogens, contamination of the water table, etc.). In the systemic approach, the limiting factor is balanced along with other growth factors, promoting healthy environments for crop development. The reductionist practices depend little on the context in which they will be employed. Employing the systemic approach, however, demands fine-tuning since the practices should be adapted in situ as they are site specific.

[19] The simplicity of the statistical treatment, taking random sampling and the estimate of averages and variance as the main focus of scientific research, directs the analyst's thinking towards predetermined indicators, ignoring factors that are unforeseen but always present in the complex ecological and socioeconomic relations in the agroecosystem. This simplifying approach to the analytic process leads to the loss of a much broader set of data and information essential to understanding the agroecosystem (Petersen and Silveira 1999).

[20] In everyday language, the term 'model' has at least three acceptations. As a substantive, the model implies a representation; as an adjective, it implies an ideal; and as a verb, to model means to demonstrate. These three meanings converge in the scientific usage. In our building of models, we create an idealized representation of reality in order to demonstrate some of its properties (Santos

2002). As conscious products of a distancing in relation to reality, models allow us to return to the real world with indefinitely renewable questions and inquiries (Bourdieu, Chamboderon & Passeron 1999).

[21] The approximative approach corresponds to an incomplete objectification of reality as, indeed, good scientific practice always preaches (G. Bachelard 2004). Self-contained knowledge building processes, which leave no space for doubts and ambiguities, produce fragile truths that quickly reveal a failure to match the objective world. The rejection and systematic doubting of previously produced knowledge comprises one of the basic principles of the advance of knowledge itself. In adopting this epistemological perspective, the method is founded on a process of knowledge building aware of its own insufficiencies and virtues.

[22] The semistructured interview has the characteristics of an open conversation (dialogue), focused on particular topic. It differs from a formal interview, based on a closed questionnaire, that limits the dialogical interactivity between interviewers and interviewees. The closed questionnaire has the advantage of gathering precise data and information capable of being tabulated and compared. On the other hand, it has the disadvantage of narrowing the scope of the interview, preventing aspects important to the comprehension of the agroecosystem from being identified and recorded. The semistructured interview is conducted using an interview guide that can be adapted to circumstances. Although some closed questions can be included in the guide, the methodology emphasizes dialogue steered by open questions.

[23] According to Polanyi (2012), economy can be apprehended in two senses, the substantive and the formal. “The latter derives from logic, the former from fact” (ibid: 294). “The substantive meaning of economic derives from man’s dependence for his living upon nature and his fellows. It refers to interchange with his natural and social environment, in so far as this results in supplying him with the means of material want satisfaction… The formal meaning implies a set of rules referring to choice between the alternative uses of insufficiency resources” (ibid: 293 and 294).

[24] As Cassol et al. (2016) warn, this conceptual distinction should not hide the fact that the conventional/capitalist market is also a socially regulated construct. The aspect emphasized in this distinction is the fact that, as institutions also regulated by mechanisms of reciprocity, nested markets ensure greater autonomy and capacity for control over the commercial transactions undertaken by the social actors involved. Additionally the concept stresses the fact that the institutions, norms and collective actors that structure these markets emerge and operate in a context dominated by conventional markets, configuring a situation involving a latent or expressed conflict of interests.

[25] The *Framework for Evaluating Management Systems Incorporating Sustainability Indicators* (the MESMIS Framework following its Spanish acronym) is a methodology developed by four Mexican institutions in the 1990s: Interdisciplinary Group for Appropriate Rural Technology (GIRA following its Spanish acronym), the Centre for Ecosystem Research at the National Autonomous University of Mexico, the Southern Frontier College and the Centre for Research in Farming Sciences at the Morelos State Autonomous University. MESMIS is an interdisciplinary methodology based on theoretical contributions

related to complex and adaptive systems, systemic self-organization processes and agroecology. To these theoretical frameworks, the authors added elements from the then emerging academic debate on attributes of sustainability in agriculture (Astier et al. 2008).

[26] Relativism considers the viewpoints of actors valid, stressing that they have a relative value according to their differences of perception. Unlike positivist approaches to knowledge building, the relativist perspective does not seek to establish absolute, universal and unquestionable truths or values.

[27] The systemic attributes should be comprehended solely as guides orienting the analysis and not as characteristics immanent to the analyzed agroecosystems. Although attributes can be analyzed individually, they mutually influence each other. Hence the option to guide the analysis according to attributes specified by objective parameters and criteria should not give way to the use of reductionist and mechanistic interpretations regarding agroecosystem's qualities.

[28] The 'Technological and Administrative Task Environment' (TATE) is a concept developed by Benvenuti (apud Ploeg 1990) "to describe the network of market-agencies and associated institutions to which farmers are tied both economically and technically (agricultural industries, banks, trade consortia, extension services, etc.)… It is from TATE that the farmer obtains those elements which are necessary but which he cannot independently ot fully develop himself. TATE therefore forms the embryo of a specific division of labor between head and hand (i.e., TATE expresses the separation of what in craftsmanship, to large extent, still forms a unified whole)" (idem:107).

[29] The parameters are presented in the section below, which provides an example of application of the method.

[30] The spreadsheets compiled for the diachronic (retrospective longitudinal) and synchronic (transversal) analyses are available at www.aspta.org.br/2015/05/metodo/

[31] The project was financed with resources allocated to Tender MCT/CNPq/CT-Hidro No. 36/2013 , particularly in the thematic line "Water and soil management on areas undergoing desertification."

[32] The Brazilian Semi-Arid Alliance (ASA) is a network formed by more than three thousand civil society organizations that work to propose and develop policies for "living with the semi-arid region".

[33] The "Training and Mobilization Program for Living with the Semi-Arid Region – A Million Rural Cisterns" (P1MC) aims to construct cisterns to catch and store water for human consumption. The "One Land and Two Waters Program" (P1+2) aims to implant different technologies designed to manage rainwater for the purpose of food production. The "Seeds of the Semi-Arid Program" was launched later with the aim of fomenting seed security systems in the region's family farming through support for the constitution of territorial networks of community seed banks. For more information on the programs, see http://www.asabrasil.org.br/

[34] P1MC and P1+2 reproduce practices and perspectives consistent with the notion of endogenous rural development, a development pattern based on the mobilization and redynamizing of resources available locally in the rural territories.

[35] Among the richest and most complete bases of empirical evidence on the effects of these programs on the life of rural families and communities, we can highlight the collection 'O Candeeiro' ('The Lamp'), composed of a collection of more than 2,200 information bulletins produced by ASA's organizations based on the documentation of life histories in the format of bulletins. The collection is available at http://www.asabrasil.org.br/acervo/o-candeeiro (consulted 04/04/2017).

[36] Taking into account total rainfall amounts, this period has been identified as 'the biggest drought' of the last 100 years (Silva 2017). Despite the severity of the phenomenon, there is a general conviction that its negative social effects have been significantly lower compared to those of previous such events (Osava 2017).

[37] The ten analyzed agroecosystems correspond to what the literature conventionally called 'traditional farming,' that is, a mode of production that makes use of local resources and makes little use of production factors acquired in the markets (Schultz 1983). Generally speaking, the low employment of commercial inputs results from the limited financial capacity of the families. It thus involves an autonomy derived 'from restrictions' and not necessarily 'from choice.' For this reason, subsidized rural credit is considered one of the main instruments of public policies for the transformation of traditional farming towards an entrepreneurial mode of production.

[38] Connectivity favors the material and information exchanges necessary for the operation of socioecological systems. The connections between the systems in the ecological and/or social landscape are essential for the mobilization of (tangible and intangible) resources necessary for recuperation of the ecosystem after a disturbance.

[39] Diversity of responses and functional redundancy are two key qualities for confronting disturbances of environmental and/or social origin. Both the qualities are provided by the diversity of elements in the system's structure, a characteristic associated with three interrelated components: variety (number of different elements); equilibrium (number of units of each element); and disparity (level of differentiation between some elements and others). Redundancy is a quality that provides a higher level of security to the system since it functions as an internal compensation mechanism in response to the deactivation of one or more of its functional elements (Biggs et al. 2012).

[40] Long and Ploeg (1994) point out that the classification schemas conventionally employed in the analysis of real life farming contexts constitute guidelines for the redistribution of public resources to the different kinds of production units. In this sense, they involve a considerable exercise of power since they are employed to legitimize some political-economic projects in detriment to others. Hence the discernment and legitimization of rural development trajectories congruent with the agroecological perspective include the use of approaches to the description and analysis of the heterogeneity of family farming capable of reflecting the economic rationalities adopted in the management of agroecosystems.

[41] Evaluations of public policies are very often limited to assessing the support activities of rural development processes, such as the volume of financial resources utilized, the number of items of equipment sold, the number of infrastructures built, the number of families assisted through capacity

building activities, and so on. One of the most eloquent and ironic examples of this limitation in the policy evaluation processes was the adoption of the indicator “number of tractors sold” as one of the main means of verifying the success of a public program whose objective could not be more explicit: the Pronaf ‘More Food’ program.

3.3 - Artículo 3 - Institutionalization of the agroecological approach in Brazil: advances and challenges

Referéncia:

Petersen, Paulo, Eros Marion Mussoi, e Fabio Dal Soglio. 2013. "Institutionalization of the Agroecological Approach in Brazil: Advances and Challenges". Agroecology and Sustainable Food Systems 37 (1): 103–14. doi:10.1080/10440046.2012.735632.

Abstract

This article sketches a brief panorama of the advances and challenges involved in the implementation of the agroecological approach in Brazilian institutions. It begins with an account of the struggles of rural social movements working at the deepest grassroots level of the country's 'agroecological field.' The processes that led to the creation and development of the National Agroecology Alliance (ANA) and the Brazilian Agroecology Association (ABA-Agroecologia) are presented as a key part of the construction now under way. Taking as a baseline the evolutions in the internalization of Agroecology in official teaching, research and rural extension services, the article identifies some of the powerful practical, theoretical and politico-ideological obstacles preventing the rupture with the paradigm of modernization on the part of State institutions.

Key-Words: Political Agroecology; Brazil

Situating the Brazilian agroecological field in historical context

After five centuries of social, economic and ideological domination by the agrarian elites, today in Brazil we can observe the emergence of a broad social process looking to build alternatives to the environmentally predatory and socially excluding patterns of land occupation and use implanted since the beginning of European colonization (Pádua 2002). Although the country's marginalized rural populations have never been passive in the face of the serious denial of basic rights experienced by themselves over the course of history (Oliveira et al. 2008), the current situation of rural social movements includes unprecedented characteristics that deserve to be highlighted (Petersen & Gomes de Almeida 2007; Wolford 2010).

Firstly it should be emphasized that, despite their many diverse forms of expression, rural social organizations are slowly converging on a number of consensuses concerning the changes needed to overcome the dominant pattern of land occupation and use, allowing peasant family farming to expand and become firmly established in the country. As well as the historical fight for access to land and for the implementation of basic rights of citizenship, the consensuses now being built include a new political-conceptual dimension: the socioenvironmental sustainability of peasant production. Given a situation in which tens of thousands of families are forced to abandon their properties each year due to unsustainable living conditions, it is clear that improving access to land through Agrarian Reform will not be enough to secure the long-term development of family-based farm production in Brazil. Critiques of the patterns of technical and socioeconomic organization inherited from the Green Revolution have matured among rural social organizations and movements as it has become clear to them that access to public policies designed to disseminate these patterns has not provided adequate conditions for the social, economic and environmental reproduction of family farming production units.[1] Much the opposite: they have subjected family producers to technological dependency, ever higher production costs and indebtedness, combined with the ecological degradation of agroecosystems and pesticide poisoning among humans (Ana, 2006; Guanzirolli et al. 2010; Bolliger & Oliveira 2010).

This increasing incorporation of the critique of industrial farming's production patterns by the national leaders of rural social movements cannot be properly understood without taking into account the vigorous emergence of alternatives developed by family farmers and their local organizations, actively responding to the denial of rights and processes of economic exclusion generated by agricultural modernization. A shared trait of these responses can be identified in the innovative forms of ecosystem management based on technologies that valorize local resources, guarantee high levels of autonomy to family economies and, at the same time, preserve the environment and health of producers and consumers.[2]

The second distinctive characteristic of the current historical context of rural social movements is related precisely to the growing national coordination of these autonomous local/regional initiatives designed to promote technical, economic and organizational alternatives for family-based farm production. The main spaces for the expression of this emerging and evolving dynamic are the National Agroecology Alliance (Articulação Nacional de Agroecologia: ANA) and the Brazilian Agroecology Association (Associação Brasileira de Agroecologia: ABA-Agroecologia) (Caporal & Petersen 2011).

However this evolution towards the internalization of the agroecological paradigm by civil society organizations is unfolding in parallel with the Brazilian state's entrenchment of conventional forms of production centred around monocrops and large agroexport farm unities. Based on a political economy pact reformulated in the1990s, the agribusiness sector maintains the initiative in terms of influencing State policy guidelines, reasserting its dominance at political, economic and ideological levels (Petersen 2009). In operation since the Fernando Henrique Cardoso government (1995–2002), this pact combines the government strategy of boosting economic growth with revenue derived from farm commodity exports with the maximizing of profits by agribusiness groups from the large-scale farming, agroindustrial and financial sectors.

The tension between these two contradictory trends means that Brazil is today exalted by the ideologues of modernization as one of the world's largest agricultural powers thanks to the occupation of vast areas of land by modernized monocrops produced for export (Tollefson 2010; The Economist 2010) while at the same time being recognized as a benchmark for actions promoting Agroecology, family farming, and nutrition and food security (Action Aid 2010; Schutter 2012).

This political collision, related to distinct conceptions of development, cannot be decided in favour of socioenvironmental sustainability without implementing a strategy of mass occupation of rural areas by agroecological experiences as a material means of production and a source of inspiration for public policies. The Political Charter of the 2nd National Agroecology Encounter provides an analytic expression of this viewpoint:

> An increasingly significant number of male and female workers and their organizations throughout the country have understood that only Agroecology will have the political capacity for transformation if effectively developed through concrete policies that guarantee that the needs of family producers and society as a whole are met. At the same time as they are experimented and disseminated locally, innovative agroecological practices comprise the embryos for the new model being built and that is already inspiring the formulation of a collective project at national level (ANA 2006).

The challenge of connecting agroecological practice with agroecological theory so that this collective project can come into historical force requires the continual maturation of an agroecological movement capable of channelling society's living forces so that the paradigm of modernization is transcended in practice, theory and politics. The experiences of constructing the National Agroecology Alliance and the Brazilian Agroecological Association, along with the challenges they have generated, provide a rich source of teaching and inspiration towards this end.

ANA and ABA-Agroecology: expressions of an emerging movement

Although practices of social experimentation designed to respond to the productive, economic and environmental challenges provoked by the dynamics of agricultural modernization have flourished since the 1970s, evinced especially in the pro-active capacity of the Grassroots Ecclesiastical Communities (Comunidades Eclesiais de Base: CEBs) linked to the Catholic Church, the systematic construction of an agricultural alternative to the Green Revolution model only began to take shape in the early 1980s following the encounter between these innovative local dynamics and a more intellectualized sector of society that had been developing a critique of the processes of agricultural transformation taking place in the country (Petersen & Gomes de Almeida 2007).

The political setting was exceptionally favourable, involving the weakening of the military dictatorship, the progressive regaining of public freedoms, the resumption of the organizational processes of popular movements and the intensification of the debate on alternatives for the democratic development of society. Notable aspects of this historical moment include the creation of NGOs and the action of professional associations, especially the agronomists, as precursors in the elaboration of a critical assessment of modernization in farming. Key technical and conceptual contributions were made by professionals already armed with reference works critical of industrial farming.[3]

Later, from the end of the 1980s, what was then called alternative farming acquired greater conceptual and methodological consistency with the arrival in Brazil of the core scientific texts of Agroecology. Decisive contributions to this arrival were made by the publication in Portuguese of key books (Altieri 1989; Gliessman 2000) as well as the connection between Brazilian NGOs and organizations from other Latin American countries, especially those belonging to the Latin American Consortium on Agroecology and Development (CLADES).

These theoretical contributions also arrived through professionals who trained in Agroecology at US and European universities.

Possessing an epistemological framework that allows a better understanding of the reality in which peasant family farming lives and works (Norgaard 1989; Altieri 1989), the agroecological approach opened up new horizons for the development of methodologies more consistent with the objective of promoting an alternative form of agriculture to the Green Revolution.

The accumulation of local experiences explicitly identified with Agroecology and their spread throughout the different regions of the country helped increase the visibility of the decentralized processes led by local and regional networks of innovation. It was in the wake of these dynamics of approximation and mutual recognition that the proposal emerged and gained force to create a national alliance, which would value and take advantage of the diversity of decentralized initiatives already being implemented and enable the expression of the agroecological field as a united front (Gomes de Almeida 2009).

The formalization in 2001 of the proposal to hold the 1st National Agroecology Encounter (I ENA) resulted from the dissemination and interrelations between multi-actor networks identifying themselves with the agroecological proposal. Held in June 2002 in Rio de Janeiro with the participation of 1100 people from all regions of Brazil, I ENA was conceived with the purpose of increasing the visibility of concrete experiences in agroecological innovation, placing them at the centre of the debates. The principal political follow-up to I ENA was the creation of the National Agroecology Alliance (ANA), coordinated by the varied set of entities (social movements, regional networks, professional associations and NGOs) originally involved in convoking the event.

In this process, the encounter between social practices based on Agroecology with agroecological theory proved to be an essential element in building and intensifying social forces around a project capable of transforming Brazilian agriculture. It was only after this process of translation and mutual fertilization between the theory and practice of Agroecology that the scientific knowledge brought by specialists ceased to be perceived as an outside imposition or the expression of unquestionable truths and became incorporated as inputs towards local innovation. But for this evolution to take place, it has been essential for corresponding evolutions to unfold in the practices of scientific-academic institutions.

Notable advances have also been made in Brazilian this sphere. Although this process has so far been unable to redirect the conceptions and practices of the majority of institutions, the seeds for this change have been widely disseminated and are now being germinated through the work of educators, researchers and rural extension technicians who, individually or collectively, innovate in the form of understanding and participating in the production and sharing of knowledge towards rural development (Petersen et al. 2009).

The creation of the Brazilian Agroecology Association (ABA-Agroecology) in 2004 represents a landmark in this evolving process. With the principal objective of Uniting in its membership all those who, professionally or otherwise, dedicate themselves to Agroecology and related Sciences (Association Statute), ABA-Agroecology assumes the challenge of maintaining and strengthening scientific-academic spaces, such as congresses and seminars, and promoting the divulgation of agroecological knowledge elaborated in a participatory form through publications. Furthermore it is committed to engaging in politics to defend peasant family farming. Having already hosted seven Brazilian Agroecology Congresses, ABA-Agroecology is today recognized as a key interlocutor on issues related to the incorporation of the agroecological perspective in official teaching, research and rural extension institutions.

Agroecology in official teaching, research and rural extension institutions

The capacities to propose and influence policy acquired by civil society go a long way to explaining the significant advances that have been made by the Brazilian State too over the last decade and a half. At different levels of conceptual and methodological consistency, Agroecology has been assimilated as a reference point in the projects and programs of a variety of federal, state and municipal government bodies. Even where the actions are merely symbolic, it is gradually breaking the paradigm of modernization that until very recently reigned exclusively in the discourse and directives of these institutions.

In the area of formal education, there are already more than one hundred courses in Agroecology or with different approaches to the agroecological perspective, spanning from secondary and undergraduate education to initiatives at MA level and research on doctoral programs (Aguiar 2011).[4] One of the major obstacles encountered in terms of fully implementing an agroecological approach in these innovative initiatives derives from the departmentalized structures of the teaching institutions. Although there is increasing support for educational projects based on a multidisciplinary or interdisciplinary perspective, the

structural segmentation resulting from the large areas of knowledge generates powerful obstacles to any systemic approach, one of Agroecology's core methodological premises. Moreover the positivist traditions deeply entrenched in academia generate difficulties in terms of implementing an agroecological epistemology (Norgaard 1989), in particular such that knowledge building processes value and take advantage of the dialogues between scientific and popular knowledge. An important innovation in this area was the creation of teaching and rural extension nuclei of Agroecology in universities and technical colleges, enabling the integration of academic staff and students from different disciplines in fertile learning environments based on direct interaction with rural communities (Caporal & Petersen 2011).

Also in the field of agricultural research, some initiatives began to take shape for institutionalizing the agroecological paradigm in the practices of public organizations at national and state level. One of the facts worth highlighting in this regard was the launch in 2006 of the Reference Framework in Agroecology by the Brazilian Agricultural Research Corporation (EMBRAPA 2006). This document was identified as a provisional sedimentation, the result of the accumulations made over a long though little visible trajectory of constructing the agroecological approach within EMBRAPA, shaped by researchers who either individually or in small groups adopted this approach, frequently against the tide of institutional orientations (Petersen 2006).

After some years executing projects conceived on the basis of the theoretical-conceptual foundations established in the Reference Framework, another level of sedimentation is necessary for the institution to move beyond its operational routines linked to the notion of technology transfers, since the latter is itself a powerful obstacle to the full implementation of the agroecological paradigm.[5] Additionally progress is needed in the approach to systemic research, in particular by incorporating investigations focused on the redesigning of agroecosystems.[6] These advances also need to be reflected in the institution's budget allocation, given that the financial resources invested in this field are negligible compared to those invested in technological innovation in conventional farming, especially in the development of transgenic varieties.

Positive evolutions are also visible in the area of technical assistance and rural extension (ATER). From 2003 onwards, strongly influenced by organizations linked to ANA in the public debates on the construction of the National Policy for Technical Assistance and Rural Extension (PNATER), Agroecology was adopted as the guiding approach for ATER initiatives in Brazil. A

variety of actions aimed towards the professional training of rural extension workers and project financing were implemented in order for official ATER entities to incorporate the agroecological perspective in their practices. However the experience of institutional transition in this direction revealed the major obstacles in this field due to the entrenched models of management and conventional technico-methodological conceptions adopted by the institutions (Mussoi 2011). Accordingly, despite the achievements made at a formal level, the diffusionist approaches that guided the creation of the official ATER institutions and continue to organize them still comprise a strong theoretical and practical limiting factor for the agroecological approach to be effectively incorporated by rural extension. Individual technical assistance practices continue to be stimulated by public calls for ATER services in detriment to the use of methods that stimulate the territorial dynamics of agroecological innovation needed for the creation of social environments capable of promoting the dialogue of knowledge practices advocated by agroecological theory.

The incipient but already significant experience of internalizing the agroecological approach in official teaching, research and rural extension organizations has shown the need for far-reaching reforms in the organization and everyday running of the same if the concept of Agroecology is to come into effective operation. A national project of systemizing experiences in "building agroecological knowledge" coordinated by ABA-Agroecologia (Cotrim & Dal Soglio 2010) identified some recurring characteristics of the most advanced initiatives in this field, among which we can highlight: a) the most innovative teaching practices in Agroecology are those that incorporate research and rural extension as a pedagogical method; b) the most effective approaches to agroecological research are those that mobilize rural communities as part of the process of formulating problems and of developing and testing hypothesis to solve them; c) the most promising ATER initiatives are those that stimulate local dynamics of technical and socio-organizational innovation that valorize the environmental, economic and sociocultural potential present in rural areas. One of the principal conclusions reached in this collective process of reflection, which involved the participation of 72 groups and institutions from across Brazil, is that the institutionalization of practices for building agroecological knowledge demands overcoming the excessive segmentation of functions between teaching, research and rural extension and a radical review of the roles played by the actors most directly involved in these activities, especially by emphasizing the proactive contributions made by male and female farmers to innovation processes (Petersen 2011).

Structural obstacles to the advance of Agroecology

Although many policy instruments have been launched by the Brazilian State with at least the nominal objective of supporting agroecological transition processes, the brief presentation made above, centred on teaching, research and ATER institutions, has looked to show the structural inadequacy of the institutional frameworks that regulate state action in order for this objective to be attained. One of the fundamental reasons for this is that the planned intervention approach7 that ideologically legitimizes the paradigm of modernization remains the dominant underlying principle in the elaboration of public instruments in support of development.

Conceived from a top-down interventionist viewpoint, the policies supporting Agroecology end up confining it as one more sector of agriculture. Given the sector-based logic that informs the elaboration and implementation of these policies, the dominant model is not itself called into question, since, according to the current conception of those formulating the policies, there is room for various kinds of farming.[8]

In assessing the advances made by the set of public policies launched by the Lula Government to promote Agroecology, Weid (2006) pointed to the structural dispersal of the State and its instruments as one of the main obstacles.

> Not only is the government unable to maintain a coherent set of policies for farming, it is also unable to integrate the various components of the development support policies. Each of these policies follows its own logic with distinct instruments that require considerable effort from development workers and farmers themselves in order to access them (Weid 2006).

Pursuing his analysis, Weid (2006) highlights the problem caused by the incompatibility between the temporal horizons of the government, focused more on the execution of programs and projects, and those of society, centred more on continuous development processes. In the face of public administration cycles determined by the need for concrete and visible results over the short-term, the perspective of sustainability, which by nature projects results into a distant future, ceases to be a central concern in political decision making. Aggravating the problem, the budget execution of the Executive is guided by one-year

projects, which translates into serious problems in the release of financial resources to provide material support to the on-going activities related to rural development programs. The combination of the fragmentation of policies in space (the focus on administrative sectors) and time (the focus on the short term) imposes serious obstacles to the transition of public institutions from the perspective of agroecological development.

Overcoming this sector-based approach means recognizing that it is imperative that the institutional frameworks regulating rural development also undergo structural changes. Only in this way will the enormous transformative potential existing in civil society, especially in the family farming communities and organizations, be able to be channelled, allowing the systemic agrarian crisis to be overcome by widespread adoption of the agroecological approach.

A few final words

There seems no doubt that over the last 15 years we have experienced an 'affirmation bubble' in the agroecological field. However the fear remains of a growing conceptual confusion that could undermine the adoption of Agroecology, especially as a public policy. The recent issue of the presidential decree instituting the National Agroecology and Organic Production Policy (PNAPO) presents itself in the current setting as an unparalleled opportunity for the civil society organizations and social movements identified with the agroecological proposal to channel their efforts towards elaborating proposals and exerting political pressure. A set of proposals has been elaborated by ANA and ABA-Agroecology in order for PNAPO to become an instrument capable of guiding public initiatives that favour the transition from the dominant model of rural development to more sustainable patterns that take family farming as their sociocultural base and that penalizes the negative externalities of agribusiness and work to impede its expansionist dynamic.

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Notes

[1] The Combined Meeting of Workers and Rural, River and Forest Peoples, held in August 2012, represented a landmark in the building of convergences. For the first time the principal rural social movements made explicit their decision to adopt Agroecology as the guiding framework for implementing structural transformations in rural Brazil (Encontro..., 2012).

[2] The social construction of local markets, which allow food production and consumption to be brought closer together, is another expression of these actively constructed responses to the processes of corporative concentration in the agrifood systems (Wilkinson, 2008).

[3] A key role in the process can be attributed to Ana Maria Primavesi and José Lutzemberger, two prominent intellectual leaders in this nascent movement.

[4] The curricula of many of these new courses presented as 'agroecological' are shaped by the promotion of organic farming based on input substitution and adopt conventional forms of teaching.

[5] Despite the undeniable advance that it represents, EMBRAPA's recent launch of a portfolio of technologies generated for ecologically-based farming systems reveals the difficulty of breaking with the diffusionist approach founded on the logic of technology transfer. For further information see: http://www.embrapa.br/embrapa/imprensa/noticias/2012/setembro/3a-semana/embrapa-lanca-portfolio-com-tecnologias-para-agricultura-organica-e-agroecologia (accessed on 23/09/2012).

[6] The EMBRAPA research system includes two national level projects that have been generating a significant volume of technical information. However these results remain linked to the 'input substitution' approach, which, in practice, does not favour the expansion of the 'agroecological paradigm' within the institution (Mussoi, 2011).

[7] As part of its process of legitimization, the modernization of farming relied on a powerful ideological offensive that was able to associate orthodox economic theory with a scientific-technological paradigm under construction. However the affirmation and dissemination of the productivist paradigm in material terms relied on the definitive intervention of National States and their apparatuses. The interventionist-type development projects depend on discourses that promote the idea that the problems of development are better approached when, through mechanisms of diagnosis and prescription, they simplify the complex reality into a series of realities taken to be independent by the sector-based approaches that organize the State. This image of intervention policy and processes is reinforced by the notion of a 'project cycle' that situates various activities (definition of the problem, formulation of alternatives, policy design, implementation and evaluation of results) in a linear and logical sequence (Long, 2007).

[8] Indeed the rhetoric of coexistence has been a powerful device employed by proponents of agribusiness in the political arena in which the debates on rural development take place. This rhetoric is applied at various geographical scales with the purpose of legitimizing the progressive expropriation of family farming's means of production. At a macro scale we see the occupation of entire territories by

monocrops under the allegation that other territories are granted to family farming. At local level the claim is made that conventional and organic farming, or transgenic and non-transgenic agriculture, can coexist when it is well known that the dispersal of pesticides and the pollen of GMOs does not respect the physical limits of the production units. At both scales the rhetoric of coexistence obscures the fact that what is under dispute are the territories and that the territorial rights of family farming are being violated.

3.4 – Artículo 4 – Hidden Treasures: Reconnecting Culture and Nature in rural development dynamics – a case from Brazilian semiarid region –

Referéncia

Petersen, Paulo 2015. "Hidden Treasures: Reconnecting Culture and Nature in Rural Development Dynamics". In Constructing a New Framework for Rural Development, organizado por Pierluigi Milone, Flaminia Ventura, e Jingzhong Ye, 22:157–94. Emerald Group Publishing Limited. doi:10.1108/S1057-192220150000022006.

Abstract

Fighting the drought. Based on this idea, for almost two centuries now the Brazilian State has elaborated policies and programs intended to stimulate rural development in the semiarid region. It is this idea which has nourished the illusion that immense infrastructures need to be built to capture, store and transport large volumes of water in order to supply production activities in the region. Associated with this proposal is the attempt to reproduce the same pattern of development adopted in other Brazilian biomes, the main characteristic of which is the use of monoculture practices on large properties managed according to entrepreneurial mode. However the rich social experience promoted by rural worker organizations in the region challenges this model by proposing *living with the semiarid* (Convivência com o Semiárido: in Portuguese) as the guiding principle for alternative trajectories of development. Inspired by the experience of territorial development under way in the Agreste da Borborema region of Paraíba state, the article shows that the evolution of these new paths of development depends on revitalizing and dynamizing locally available resources, such as ecological potentials, social mechanisms for organizing labour and for producing and sharing knowledge, local forms of connecting food production to consumption, and so on. The text concludes by emphasizing the need to design and implant institutional arrangements that enable a more balanced distribution of power between the State and civil society organizations, thereby allowing the latter to assume a more substantial role in identifying, mobilizing and managing endogenous resources that underpin self-centred development strategies.

The role of our unions is to discover the treasures hidden in our municipalities

Zé Pequeno

(family farmer from the Agreste region of Paraíba)

A hidden treasure

Manoel Apolônio de Carvalho, better known as Nel, is a family farmer from Sergipe state in the Northeast of Brazil. His life trajectory is similar to those of tens of thousands of rural inhabitants from the Brazilian semi-arid region who 'tried their luck in the South,' in most cases with the intention of eventually returning to their land of origin to pursue a living as farmers. This veritable saga of migration of Northeastern peasant to the main dynamo of the Brazilian economy, the Southeast region, was beautifully described and analyzed by Afrânio Garcia Jr. in his book "O Sul: o caminho do roçado"– "The South: the path of the swidden"(Garcia Jr. 1990). Opposing the interpretations then in vogue, which associated this ceaseless migratory flow with the supposedly inevitable depopulation of the rural Northeast, Garcia Jr. perceived that the return to the rural world, to the place of origin, could constitute the motive for leaving for the South (ibid: 13).

The return to the swidden was also the path taken by Nel after a brief period spent working as a bricklayer in São Paulo. During his time as a migrant, he learnt to make pre-moulded slabs of cement for use in the construction of swimming pools, a technique that he later tested back home in the Northeast to build cisterns for storing rainwater. Since it resulted in a cheaper and more resistant final product than the traditional brick cisterns, the technique soon attracted the interest of his neighbours.[1] Nel was subsequently asked to build cisterns all across the region, opportunities that proved valuable in training of other farmer-bricklayers and in gradual perfecting his invention.

For Nel, the social acceptance of slab cisterns was proof of his invention's success. However he could not know at the time that his intellectual enterprise of adapting a swimming pool construction technique, learnt by himself in the country's biggest and wealthiest city, to his home community would contribute, years later, to meeting a vital need of millions of people in the Brazilian semi-arid region. This impressive increase in scale was enabled by the

implementation of the One Million Rural Cisterns Program (P1MC),[2] an initiative conceived and executed by the Brazilian Semi-Arid Alliance (ASA),[3] a civil society network composed of more than a thousand organizations active in the region's eleven states.[4]

As well as allowing widespread dissemination of equipment capable of storing water and maintaining its quality for human consumption during dry periods of the year,[5] P1MC reproduces at a larger scale some of the procedures adopted by Nel and his companions during the first phases of disseminating the novelty: (1) capacity building for local bricklayers so that the knowledge is independently put into practice and adapted by the communities; (2) by stimulating the practice of peasant reciprocity, community work is mobilized to perform manual activities, such as digging a hole in the soil to hold the cistern; and (3) the construction materials needed to make the cisterns (cement, sand, etc.) are purchased from local markets. The combined application of these three elements in the localities covered by the program has afforded a series of positive effects that extend far beyond the direct (and more visible) impacts on the food security and health of rural families.

Analytically speaking, P1MC reproduces practices and perspectives consistent with the notion of endogenous rural development, a pattern of development founded on the activating and redynamization of resources locally available in rural territories (Long and Ploeg 1994). These local resources span both ecological and sociocultural potentialities, the latter including the capacities for local innovation needed for the constant adjustment of technical and socio-organizational systems to the contextual alterations that affect ways of life in the rural world.

Omnipresent and invisible

This succinct description of Nel's trajectory and his invention is presented here as an illustration of a reality that is at once commonplace and extraordinary in the rural world. Commonplace because farmers and their organizations do not simply remain passive in the face of realities that for them are very often oppressive. They are social actors: in other words, they possess the capacity to process social experience and delineate forms of confronting life, even under the most extreme forms of coercion (Long and Ploeg 2011: 25). Although omnipresent in the universe of peasant life, this capacity for social agency is widely neglected and, thus, concealed by the paradigm of agricultural modernization that since the 1960s has dominated the public policy frameworks for rural development in Brazil (Petersen 2013). In the

wise and beautiful words of Zé Pequeno, the Paraiban farmer quoted in the epigraphy, these actors are the hidden treasures of peasant communities.

The extraordinary side of Nel's story is that he and his innovation emerge as discovered treasures, widely recognized and valued through a public program conceived and executed by a civil society network with an extensive grassroots presence in Brazil's semi-arid region. Additionally, this program was designed in a way that combined the two sides of Nel's innovation: the slab cisterns (the hardware) and the social organization to construct the cisterns (the software).

The combined dissemination of hardware and software through P1MC distinguishes ASA's initiative from the current official interventions directed towards rural development. In this case the central distinction is that the software programming government initiatives obeys a linear model of innovation, according to which some actors assume the function of managing the innovations (the hardware), others are involved in transferring the innovations (or disseminating them) while the farmers themselves assume the role of receivers (or adopters). In this linear and top-down conception of innovation processes, the farmers are individually and collectively envisaged as passive recipients of the interventions of public programs, thereby downplaying their own creative capacities to recombine locally accessible and controlled material and non-material resources in order to solve locally defined problems.

As well as exacerbating dependency on exogenous solutions, the imposition of diffusionist schemes by the rural development programs atrophies the potential of the kind of social agency responsible for the emergence of slab cisterns and a myriad of other peasant innovations that, unlike Nel's invention, remain hidden as treasures that could be revealed and incorporated into the dynamics of rural development.

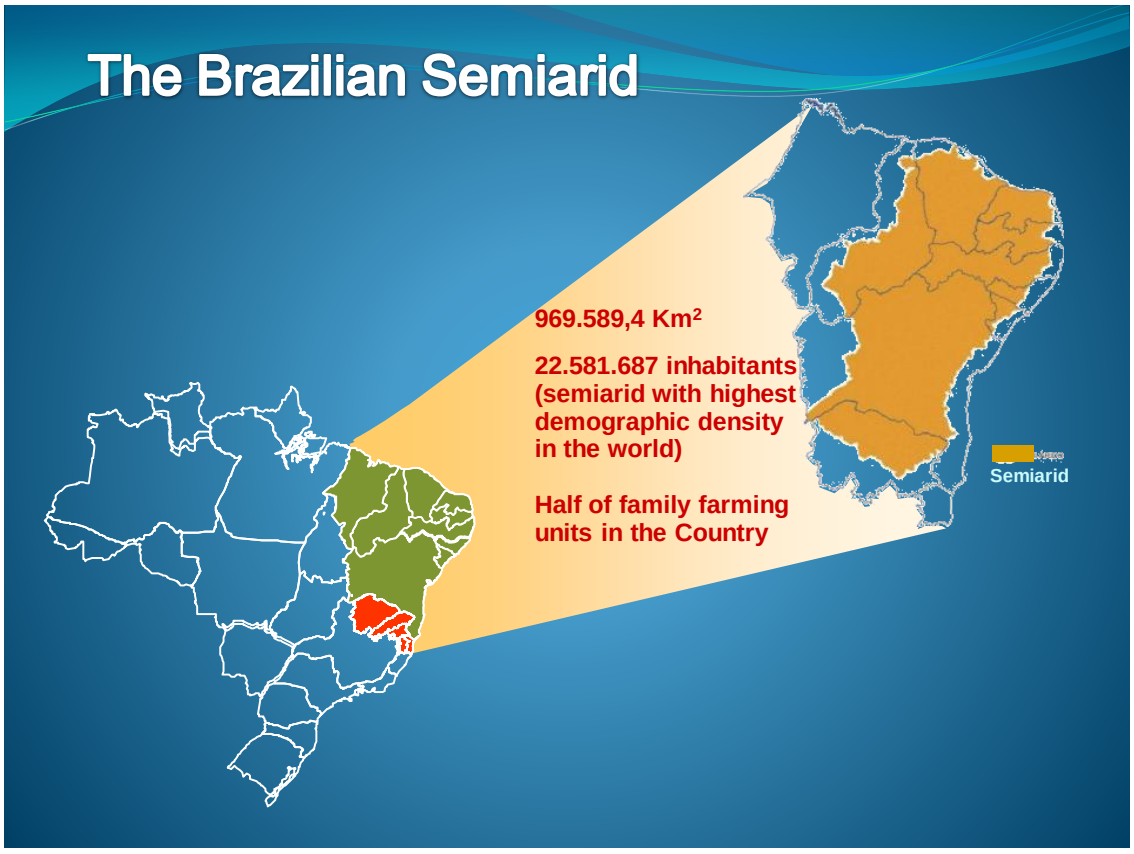
Taking as its reference point the reality of Brazil's semi-arid region and, more particularly, the Agreste region of Paraíba state, this chapter examines the theme of peasant farmer innovation by seeking to relate it to the emergent dynamics of rural development observable in the region. By contrasting the paradigm of combatting the drought historically responsible for orienting government programs and policies in the region with the paradigm of living with the semi-arid, which has become consolidated through the initiative of civil society organizations and networks linked to ASA, the text explores aspects related to institutional design6 in the field of rural development, looking to show that the recognition and redynamization of the

role of social actors at territorial level emerges as a central challenge in moving beyond the paradigm of modernization and building the paradigm of sustainability.

The Brazilian semi-arid region and the imaginary of the droughts

In both territorial and demographic terms, the Brazilian semi-arid region is one of the largest of its kind on the planet. Covering a geographic area of 980,000 Km2, concentrated in states located in Brazil's Northeast, the region contains a population of 22.5 million inhabitants – 12% of the national population – with 44% living in rural areas, making it the least urbanized region of the country (IBGE 2010). Also concentrating more than half of the population of Brazil living in poverty (58%), the semi-arid region is still considered by some intellectual and political circles to be a problem region.

Map 1: The Brazilian Semi-Arid Region



This kind of interpretation is grounded in a deterministic bias that associates, as two sides of the same coin, the low social indicators with the recurrent droughts typical of semi-arid conditions. The narratives produced as a result of this bias imposed themselves on the

collective and political national imaginary, creating an environment that tacitly accepted the supposed historical destiny of the region to poverty and backwardness relative to Brazil's other regions. Just as this discursive recourse to geographic determinism (or divine will) has the power to induce passivity in face to a theoretically pre-ordained fate, it also functions as a powerful ideological lever for legitimizing public interventions informed by the notion of combatting the drought.

The government initiatives framed by this conception can be traced back to Brazil's imperial period in the nineteenth century. Since the Old Republic at the start of the twentieth century, these initiatives have been orchestrated by the National Department of Works to Combat Drought (DNOCS), an entity today linked to the Ministry of National Integration. The very name of the institution leaves no room for doubt that the official strategy for fighting the droughts is founded essentially on the implementation of hydraulic works designed to capture, store and transport huge volumes of water. As well as concentrating water resources in just a few localities, thereby failing to meet the demands of rural communities for geographically diffuse and functionally diverse sources of water, the so-called hydraulic solution consolidates old systems of power dominated by the agrarian oligarchies. This is because the water sources are frequently located on large farm estates, thereby reinforcing the high concentration of land ownership in the region, a characteristic common to rural Brazil whose roots extend back to the very beginning of European colonization. This double concentration of environmental assets decisive to the economic and social life of the rural world makes the poorer populations of the semi-arid region highly vulnerable to the unpredictability of the climate, thereby entrenching the unequal social structures seen in the region.

An examination of this structural setting reveal, therefore, that although the natural and social worlds are closely interconnected and to an extent coproduced in the semi-arid region, they possess distinct causalities, a fact that challenges the rhetoric used to justify extreme poverty, as well as continuation of the so-called *drought industry*.[7]

Full of opportunities, rich in life[8]

Contradicting the fatalist perspectives cultivated by geographic determinism, over the generations peasant families and rural communities from the semi-arid region have been able to develop sophisticated and peculiar strategies for managing agroecosystems and organizing social life. Founded on what is today identified as the paradigm of living with the semi-arid

(Silva 2006; Galindo 2013; Conti and Pontel 2013), these strategies have been shaped around building analogies between the technical reasoning that structures and organizes the functioning of agroecosystems and the ecology of natural ecosystems (Petersen et al. 2002). In this dynamic of agriculture-nature coproduction, farmers have been induced to exercise their creativity with the aim *of improving and innovating their forms of management [...] based on living intimately with the unwritten codes of nature* (ibid: 23).

Close conviviality with the environment is, indeed, the precondition for the ecological opportunities to be continually revealed in a natural environment at first sight hostile to obtaining dignified levels of social life (Box 1).

Box 1: Seasonal contrasts in the semiarid region

Rapidly examined by the casual observer during the dry part of the year, the natural landscape of the semi-arid region may suggest conditions unsuited to any kind of rural economic activity. A more careful inquiry, however, one which contemplates the seasonally marked climate, will instead perceive the enormous biological production potential of the ecosystems. A veritable *resurrection* takes place in the surroundings with the arrival of the first rains after the dry season. In the sequence of more or less lengthy periods of biological latency, these rains stimulate the rapid mobilization and translocation of nutritional and energetic reserves stored in special organs of plants, bringing vivid colours to the landscape in contrast to its washed out appearance during the dry spells.

Petersen et al. 2002

The socially constructed analogies only become visible when the practices of living with the unpredictable climate fluctuations are examined as a whole in a systemic approach. By developing patterns of occupying agricultural space that form mosaics of biodiversity, farming families create ecological infrastructures analogous to those of natural ecosystems, thereby reproducing the environmental services essential to the continuous regeneration of the fertility of the agroecosystems. Consequently the practices of conviviality become spatially and temporally integrated, forming strategies for multiple and sustainable use of the resources of ecological capital (this aspect will be illustrated later with examples from the Agreste region of Paraíba).

The emergence of the Brazilian Semi-Arid Alliance

Although this movement of peasant innovation has been responsible for the development of an extensive array of technologies and processes for managing production and for social organization adapted to the peculiar conditions of the semi-arid region, this knowledge for a long time passed unnoticed and/or depreciated by public programs focused on regional development.

Without doubt the approach of combatting drought plays a decisive role at the intuitive level of public administrators and intellectuals in concealing this empirical reality, linked to active popular creativity in search of better adapted means and ways of life. Reinforcing this tendency, the implantation of the agricultural modernization project in Brazil accentuated the ideological load responsible for delegitimizing the important role played by farmers and their organizations in producing and sharing knowledge on agricultural management of the natural world.[9]

It was only from the 1980s onwards and the gradual return to democracy in Brazil that civil society institutions became structured to provide systematic advice to peasant farmer organizations, seeking to associate the critique of the historical pattern of the agrarian occupation and the conservative modernization project with the construction of alternative styles of rural development. Initially associated with the idea of alternative agriculture, these organizations soon recognized that new patterns of development would emerge as the result of a social construction rooted in the huge range of productive practices and economic survival strategies expressed in the farmers' resistance to the modernizing policies, productive forces and markets that tend to expel them from the rural world (Gomes de Almeida 1991).

Today identified with the Brazilian agroecological field, these civil organizations (basically NGOs) work in rural territories dispersed throughout the country. In the context of the semi-arid region, at the end of the 1990s, after almost two decades of activity, the organizations elaborated and persuaded the federal government to implement the creation of the P1MC program (followed later by the P1+2 program), an initiative that provided the political and financial conditions for the constitution of the Brazilian Semi-Arid Alliance.[10]

By conceiving the promotion of water security in rural communities of the semi-arid region as a process of social mobilization, ASA created unique conditions for promoting the visibility and

recognition of peasant innovation as the source and motor of autonomous dynamics focused on endogenous development in the region. In its founding document, ASA highlighted that men and women from the region are entirely capable of taking their destiny into their own hands, overthrowing the traditional structures of political, hydrological and agrarian domination.[11] In a later public manifestation, the entity stated its belief in the diversity of the experiences developed by farmers in Brazil's semi-arid region and its conviction that these experiences produce knowledge that, once inter-related with academically systemized knowledge, will be transformed into knowledge capable of driving forward the sustainable development of the semi-arid region.[12]

Through these manifestations, ASA highlights its view of the role played by farmers and their organizations as actors in rural development – in other words, as agents propelling territorialized dynamics of technical and socio-organizational innovation that are strengthened by the support of its own public programs directed towards the implantation of infrastructures for supplying water to rural families and communities.

By working to promote social mobilization in this way, ASA's programs function as seeds for endogenous dynamics of rural development.[13] The conditions for the germination, development and maturation of these seeds in the different territories vary significantly according to the specific socioecological contexts involved, resulting in very different outcomes in terms of the dynamics of rural development. However these structural conditions did not emerge with the Genesis: rather they are social constructions directly related to the institutional configurations established in the specific context of the territories with the objective of strategically managing niches of socio-technical innovation.[14]

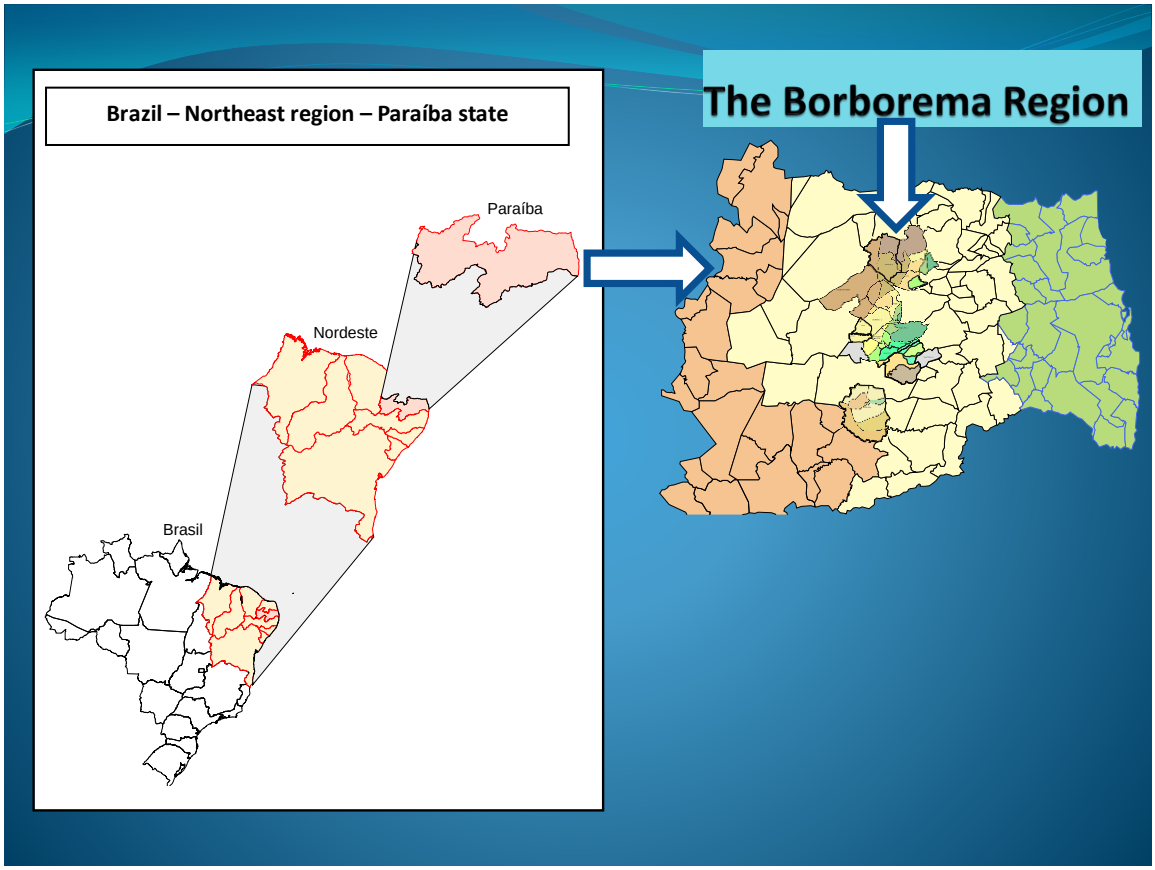
The experience under way in the Agreste region of Paraíba state is presented here as an illustration of these endogenous dynamics of innovation, embedded in the valorization of the territorial specificities and based on the idea of living with the semi-arid.

Peasant innovation in the Agreste region of Paraíba

Characterized by the dense presence of family farming, the Agreste region of Paraíba historically became established as the main food-supplying region for Paraiban society. Situated between the coast occupied by sugar cane monocropping and the cattle breeder sertão,[15] the history of the region's occupation was marked by cycles of repeasantization and

depeasantization that alternated as a function of the equally cyclical interests of agrarian elites in occupying portions of the territory in response to the rise or decline in the production of agricultural products destined for the big markets (Silveira et al. 2010).

Map 2: The Borborema Region



Though conditioned by the ebb and flow of the interests of rural businesses, these cyclical processes did not unfold historically without various forms of resistance being organized by local populations.16 Although less visible, the forms of economic and technical organization of the systems of production, today understood to be an essential mechanism of peasant resistance and struggles (Scott 1986; Ploeg 2007), played a decisive role in sustaining the open struggles marking the social history of peasantry in the region (Moreira and Targino 1997). In the interstices of the large properties and running counter to the dominant model of occupying agrarian space, founded on monoculture systems run according to a entrepreneur logic, the peasants developed economic strategies based on the diversification of food crops, sale to local markets and pluriactivity.

Because of the endless dispute over the possession of agricultural land with the large estate owners, as well as the constant fragmentation of family properties due to the intergenerational processes of division inherited land, the physical space available to assure the social and economic reproduction of family farming became more and more reduced over the decades. As a result of the declining availability of land in the region, transformations took place in how the fertility of agroecosystems was managed, including the gradual reduction until the complete abandonment of the practice of slash and burn fallow vegetation, and the adoption of management strategies focused on the agricultural intensification.

As Boserup (1981) showed, this pattern of technological transition was repeated in other regions of the world based on the trigger activation of local innovation,[17] a process of highly endogenous cultural production directed towards identifying, activating and dynamizing resources of ecological capital. In these transition processes, Ploeg (2008) identifies the peasant strategy of continuous development and improvement of the base of locally available and controlled resources.

In its studies of family farming agroecosystems in the region, AS-PTA18 identified three basic principles that interconnect and lend strategic coherence to the practices of intensifying the use and management of agricultural lands (Petersen et al. 2002): 1) the maintenance of high functional biodiversity in agroecosystems; 2) the constitution and management of stocks of productive resources; 3) the productive valorisation of limited spaces of high biological productivity (Box 2).

Technically speaking, the practices connected by these principles converge towards the optimization and regulation of the ecological processes that convert the basic abiotic resources of agroecosystems (water, solar radiation and nutrients) into biotic resources (plant and animal biomass) without the need for large quantities of external inputs that generate dependency on markets. By integrating with each other, the management practices constitute a complex and organic whole, each of them assuming a multifunctional character insofar as they engender positive knock-on (systemic) effects on the ecological and economic functioning of agroecosystems. They are, therefore, coherent with the peasant perspective of intensifying economic production without simplifying ecological reproduction (Petersen et al. 2013).[19]

Box 2: Principles of strategy in the multiple use of resources of ecological capital by peasant farming in the Agreste region of Paraíba.

1) Maintenance of high functional biodiversity in agroecosystems: In the agroecosystems managed by family farmers, exotic and native plant species are combined in time and space through production practices deliberately designed to optimize the ecological-economic efficiency of the system. Through the occupation of different ecological niches, these species perform different functions in the agroecosystem (functional diversity), increasing its stability and productivity. The biomass produced is circulated in the agroecosystem using labour practices strategically defined to synchronize management operations and reinforce synergy and complementarity between the animal and vegetal subsystems.

2) Constitution and management of stocks of productive resources: In order to reconcile the irregular and uncertain supply of rainwater in the region with the regular demands of farmers there is only one way: store water to stabilize supply. That's exactly what nature does once the native vegetation has developed biological-evolutionary mechanism to reserve water, nutrients and energy in a form that traverses dry periods. Likewise the peasant farmer systems in the semiarid region combine a set of resource-storing practices (water, seeds, animal fodder, food, capital etc...)

3) Productive valorization of limited spaces of high biological productivity: The huge environmental diversity in the semi-arid region composes landscapes in the form of mosaics in which environments with striking differences in biological productivity are located side-by-side. Since water availability for plants is the critical factor in the region's ecosystems, this diversity is essentially determined by this ecological attribute. The lower areas of the landscape (the lowlands) are generally those in which water is available for most of the year since the soils are deeper and more permeable, as well as receiving the water draining from the higher areas of the landscape. Through management practices, the farmers create areas of high biological productivity, such as domestic yards and underground dams. Despite their small territorial size, these areas play a decisive role in the economic strategies employed by family farming, whether in producing food for self-consumption or sale, or in producing animal feed.

Petersen et. al. 2002

In a longitudinal study of the transformations in the technical management of agroecosystems in the Agreste region of Paraíba over a 70 year period, Sabourin (2002) identified and described the endogenous process of innovation rooted in sociotechnical networks constituted by relations of interknowledge and proximity and by reciprocal prestations (or mutual services) in the production or redistribution of products and knowledge. In his studies of the Brazilian rural world, the author also observed that the more peasant farmer communities are closed off and/or dominated and marginalized, the more isolated, discrete or even invisible innovation becomes (Sabourin 2009). These observations highlight the importance of

territorially embedded collective action for the establishment of fertile sociocultural environments for the emergence, development and densification of social networks of farmer innovation.[20]

In the Agreste region of Paraíba, the cultural warming that enabled the dynamization and densification of networks of pre-existing sociotechnical innovation occurred as a result of the emergence of a collective actor at regional level: the Borborema Union and Family Farmer Organization Pole (or simply Pole).

The Borborema Pole: a contemporary actor of historical peasant struggles

During the movements of resistance and struggle of family farmers in the Agreste region of Paraíba in the early 1990s, a period coinciding with a decline in the union movement among rural workers, the Solânea, Remígio and Lagoa Seca unions took on the challenge of implementing a strategy of innovative action explicitly directed towards the management of socio-organizational dynamics focused on the core of the specific set of problems faced by family farmers in the region. The aim was to connect their traditional political agenda, until then generic and heavily influenced by the union movement at national level, with the reality and concrete motivations of the numerous and diverse family farming practices in the territory (Silveira et al. 2007).

This change in the focus of union activity was largely stimulated by the beginning of the partnership with AS-PTA, an NGO that began working in the region in 1993 with the goal of providing advisory to family farming organizations, based on an agroecological approach to rural development. In order to kick start the work in this field, the unions undertook a joint effort to produce knowledge on the reality of family farming and to mobilize their social bases through the experimentation with technical and political-organizational innovations.

The first participative agroecosystems appraisals led to the emergence of new perceptions of the distinct agrarian landscapes in the municipalities concerned and the corresponding diversity of their productive systems. Stimulated by the appraisals, as well as the contacts with new experiences provided by exchange visits held inside and outside the territory, a growing number of farmers engaged in experiments on their own properties and in their own communities. The interactive flows and initiatives that resulted from this process elicited new questions and demands for knowledge that reflected the breadth of the motivations and

problems to be confronted. The questions raised in the process stimulated a series of later studies and diagnoses concerning specific aspects suggested by the social dynamics of innovation.

These joint exercises in producing knowledge focused both on themes related to production strategies – such as the diversity of cultivated beans, livestock breeding systems, water resource management strategies, the use of native fruits and medicinal plants, the productive management of house yards, the use of bio-fertilizers – and to methodological and political aspects, including the participation of poor families in the innovation networks and the impact of public policies on the sustainability of regional family farming as a whole.

The evolution of the knowledge processes concerning the lived reality and the experimentations resulted in the configuration of an integrated cycle of radiating and mutually productive actions. The realization of the appraisals enabled the union leaders not only to understand better the structure and functioning of the agroecosystems in their municipalities, but above all to visualize them in all their diversity as an expression of the singular strategies of technical and economic reproduction adopted by the family farmers.

The exchange activities enabled the intensification of the interactions between farmers and comprised an important mechanism for projecting their technical, socio-organizational and political capacities. Likewise the direct participation of farmers conferred a new meaning to the production of knowledge, altering the nature of their contribution to local development processes. Simultaneously it generated a new identity associated with the social and political insertion of farmers in the organized community spaces and in union life as they become known and recognized themselves as farmer-experimenters, integrated with the emerging movement of agroecological innovation (Petersen and Silveira 2007).[21]

Institutionally coordinated by the unions, the dynamic of experimentation mobilized the growing interaction with academic institutions, which began to elaborate research projects based on issues of interest to thematic networks of farmer-experimenters organized through specific commissions – on water, local seeds, livestock breeding, yard production, market access and so on.

In a few years, a large range of innovative practices had been developed and/or adapted and incorporated in local agroecosystems. Taking as a reference point the three strategic principles

of valorizing ecological capital presented in Box 2, Box 3 presents the relation between practices traditionally adopted by the region's family farming and the innovative practices developed and/or improved through the establishment of networks of agroecological experimentation.

Box 3: Relation between agroecosystem management principles and traditional and innovative practices

Management principles	Practices	
	Traditional	Innovative
Maintenance of high functional biodiversity	• Consortia and polycultures • Use of fodder or native species • Use of local varieties • Hedge planting	• Recuperation, improvement and multiplication of local varieties • Evaluation and introduction of new varieties • Reforestation of farms • Cultivation in rows • Agroforestry systems • Green manure • Vegetable contour lines
Constitution and management of stocks	• Capital investment in the form of cattle • Claypits, cisterns, stone tanks, etc. • Domestic storage of seeds • Storage of crop leftovers as a source of fodder	• Community seed banks • Underground dams • Stone tanks • Slab cisterns and paved cisterns • Silage and haymaking practices
Valorization of limited spaces with high biological production potential	• House yards • Intensive planting in low-lying wetlands	• Underground dams • Stone barriers

Source: Petersen, Silveira and Almeida (2002)

The advance of the experimentations gradually spread and stirred the interest of unions and other family farming organizations present in other municipalities of the Paraiban Agreste. The

successful experiences in managing water resources and community seed banks acquired special visibility during the 1998-1999 drought, precisely because they assured family smallholdings greater stability and capacity to resist the adverse climatic conditions.

This fact persuaded the region's unions, then associated with a pre-existing space of coordination, the Borborema Union Pole, to mobilize their social bases in the communities in order to divulge their innovative experiences under way in the three pioneer municipalities. Through this evolution, the Borborema Pole began to present itself not only as an actor of political representation in dealings with the State but, fundamentally, as a political-organizational space unifying the set of family farming organizations around the conception and execution of a shared project of rural development for the territory.

The bases of this project were established at the start of the 2000s, based on the formulation of an action strategy centred on two inter-related axes: the first, dedicated to stimulating dynamics of local innovation through networks of farmers-experimenters; the second, directed towards elaborating and defending public policy proposals adapted to the socio-ecological peculiarities of the territory.

The Pole as a niche of farmer innovation

As a territorially referenced collective actor, the Pole plays a decisive role in enhancing the strategic coherence of the territory's actors, activities and resources, looking to identify, mobilize and interconnect them in specific socio-productive configurations. By adopting this approach, the Pole helps boost the autonomy of local social dynamics from the hierarchical and centralized logic typical of the interventionist actions of the State and agribusiness companies in the rural world. In this sense, the Pole functions as a strategic niche for farmer innovation – that is, a space relatively protected from the dominant sociotechnical regime, enabling the creation of a sociocultural environment favourable to innovation, based on the activation of ecological, social and human capital and oriented towards ensuring that the territory's farming is founded on the same.[22]

The legitimization and intensification of farmer experimentation associated with the affirmation of the 'farmer-experimenter' identity was a key element in increasing the levels of cohesion between the organizations making up the Pole. By coordinating and providing a strategic direction to the networks of farmer-experimenters in the territory, the Pole helps

them acquire independence from institutionalized systems of knowledge and presents itself to the State and market actors alike as an agent capable of inducing endogenous forms of rural development. Hence farmer innovation is a key process in the promotion of higher levels of self-determination at different geographic and social levels – from family farms to the territorial context.

However this distancing from institutionalized science is not absolute. Through partnerships established with research groups linked to official scientific-academic institutions, the network of farmer-experimenters coordinated by the Pole counts on the input of academically systemized knowledge, as well as the methodological resources of objective science to advance the process of local innovation. To this end it elaborates and participates actively in pursuing a research agenda aligned with the themes that mobilize farmer experimentation in the territory. At the same time that they help advance knowledge on the technical and economic management of agroecosystems, these partnerships play the important role of legitimizing farmer innovation in the eyes of the State. The case of participatory research on local varieties of maize illustrates various aspects of this question (see Box 4).

Box 4: Seeds or grains? Research with local maize varieties

Seen by conventional Agronomy as less productive compared to so-called *improved varieties* – which are only accessible via the markets or public programs – local varieties, locally known as *sementes da paixão* (passion seeds), have not even been officially recognized as seeds, but as grains. To demonstrate the opposite, a team of researchers from EMBRAPA (Brazilian Agricultural Research Corporation) was invited to support the network of farmers-experimenters to conduct trials to compare the varieties distributed by public programs and the passion seeds. The trials were repeated over a three year period, in three environmentally different regions and in the crop growing conditions commonly employed by the communities responsible for carrying out the trials. The results are unequivocal in demonstrating the systematic agronomic superiority of the local varieties, both in relation to the production of grains, and in relation to the production of fodder biomass (hay), an essential input for feeding cattle during the dry periods of the year.[23]

The research proved what we already knew, one farmer stated in a seminar organized for the presentation and debate of the results with public officials from federal and state spheres. Indeed this shared process of building knowledge concerning an important component of the ecological capital of the territory largely ignored by the State exerted an important role in the fight against the invisibility of the passion seeds and their stewards. Based on the feeling of empowerment provided by the research results, farmer-experimenters told the public officials that they would no longer accept the government

bodies reducing passion seeds to the status of grains[24] (Petersen et al. 2013).

In the form conducted, with the network of farmer-experimenters actively involved from its conception to the evaluation of the results, the research with passion seeds was able to disclose traditional strategies of valorizing agrobiodiversity capable of inspiring the reformulation of public policies in the area. Firstly because it showed that the use of 'improved' varieties is not the best option for a mode of farming conducted in highly unpredictable environmental conditions like those found in the semi-arid. As genotypes dependent on the presence of optimal environmental conditions, generally provided by the input of irrigation and chemical fertilizers, the improved varieties display productive performances lower than the local varieties, the latter improved through processes of local selection carried out by generations of farmers.[25] Secondly because the research findings throw into question the 'seeds versus grains' dichotomy that underlies the design of public agricultural support and credit programs. This questioning affirms that the seeds produced by farmers deserve official support. Thirdly because it shows how the farmers compare the varieties grown by themselves according to a range of different criteria and not only in terms of their physical productivity levels. The practical implication of this multi-criteria evaluation is that the farmers do not seek 'the best variety' but the best *pool* of varieties that meets their many productive and reproductive expectations.[26] Fourthly, and finally, because this pool of varieties varies from region to region as an outcome of particular environmental factors and cultural preferences. This necessity for local adaptation of plant varieties to the socioecological and cultural specificities of rural territories undermines the execution of public programs conceived in a centralized form, based on a universalist distributive logic. The practical implication of this fact is that the supply of seeds used by family farming should be ensured through the action of territorialized networks dedicated to the use, management and conservation of local varieties, emphasizing the active role of farmers as *stewards of agrobiodiversity*.

Another important aspect of the dynamics of farmer experimentation incubated by the Pole in the Borborema territory is that the latter favours the systemic coordination between the innovations and creates the objective (material) and subjective (symbolic) conditions for other novelties to be created and introduced in the agroecosystems in a coherent form. This leads, therefore, to the development of networks of interconnected innovations that remodel the sociomaterial reality of family farms.

By being coordinated in systematic networks inside and outside family farms, the farmer innovations reconfigure the structure and functioning of agroecosystems, generating positive effects on the economic productivity and resilience of family farming vis-à-vis the environmental unpredictability of the semi-arid region. A clear example of this fact was

observed in the 2012-2013 period when the family farming of Paraíba's Agreste region demonstrated a high capacity of resistance and response to the harshest drought of the last 50 years, showing a clear contrast with the devastating effects of the less severe droughts seen in previous periods.

The Pole as a political actor

The territorialized focus adopted by the Borborema Pole set it apart from the union movement's tradition, whose political agendas very frequently involve the pursuit of a generalizing approach disconnected from the real-world situation and thus distant from the specific demands, potentialities and perspectives present in its diversified social base. In this sense, the Pole emerges as an institutional innovation focused on building increased levels of governance over the dynamics of rural development in the territory.

To perform this role, the Pole establishes an interface between the grassroots social dynamics activated by farmer experimentation and the different levels and operational sectors of the State. This interface involves the establishment of connections between, on one hand, the issue-based networks of farmer innovation dispersed horizontally across the territory and, on the other, the political pressure work applied to official bodies, whose actions, when implemented on larger scales, interfere vertically on the local dynamics of rural development. The dynamics of these networks are coordinated by theme-based commissions constituted by farmer-experimenters and linked to the political coordination of the Pole. Consequently the continual updating of the Pole's capacity to propose policies to the State is directly connected to the concrete life experiences of farming families in their different forms of resistance and their everyday struggle to improve their strategies for social and economic reproduction.

Given the predominance of a political culture that combines the authority of leaders from social movements and from organizations representing family farmers, the form in which the Pole relates to the State emerges as a political-institutional novelty of extreme importance in terms of mobilizing public resources in support of endogenous development. This is because the traditional methods informing the action of the union movement tend to be fairly insensitive to the social experimentation and the strategies that implicitly gives rise from it. By employing generalizing approaches to their understanding of reality, the leaders of these movements become professionalized in their posts and, little-by-little, disconnected from grassroots social processes. Consequently they gradually become incapable of incorporating

into their political strategies the lessons contained in the diverse ways in which farming families work to resolve their problems.

The federating role played by the Pole in constructing a critical and active political awareness of the reality faced by family farming in the territory occurs at two interdependent levels: at one level, by promoting better cohesion between the formal and informal family farming organizations present in the geographic areas covered by its work; at another level, through the intermediation of community and municipal grassroots organizations, by stimulating farming families to join the networks of agroecological innovation established at a territorial level – while also enabling them to benefit from exchanges held outside the territory.

The interaction between these two levels occurs through collective dynamics of knowledge production that feed the experiences undertaken in the spheres of private action – i.e. in the family farms – and collective action – i.e. in the community, municipality and territory as a whole. Through this multiscalar and multithematic political-pedagogical approach, the networks of farmer-experimenters create an environment for social learning about the territory's reality, identifying its internal diversity – expressed in the different configurations of the agroecosystems – the range of different social actors involved and their corresponding development projects.

These learning processes combine knowledge concerning the technical and economic management of agroecosystems with knowledge concerning the governance of common assets in a community/territorial context (see the next section on innovation in institutional arrangements). Additionally they enable a critical reading of the power relations underlying the different farming styles[27] found in the territory.

This close connection between lessons learnt in the technical management of agroecosystems and the political economy of farming styles creates favourable conditions for the farmer-experimenters linked to the Pole's theme-based commissions to also work as activists in defence of public policies congruent with the development trajectories in which they are embedded. By constructing its strategies for political action through a critical reading of the local reality, the Pole establishes relations with the State in order to mobilize public resources for augmenting the resource base controlled by farming families and their communities, thereby strengthening the technical autonomy, economic efficiency and environmental

sustainability of the region's agroecosystems.[28] Some examples of this kind of work are presented in Box 5.

Box 5: Political actions undertaken by the Pole on various issues related to the process of farmer innovation in the Agreste region of Paraíba

a) The Pole's water resource commission criticized the major hydraulic works that have historically typified the State's intervention in this area. It argues instead for a conception of water management based on the decentralization of the water supply through the development of a network of small infrastructures to meet the water demands of families and communities. By working alongside other organizations from the semi-arid region, the Pole contributed to the conception of and political campaigning for the P1MC and P1+2 programs to be implemented by the federal government; b) The seed commission criticized the policies for distributing improved seeds and releasing transgenic varieties in the semi-arid region. As an alternative, it formulated and campaigned for programs in defence of local seeds and the valorization of farmers as stewards of agrobiodiversity;[29] c) The livestock breeding commission argued for the allocation of public funds for the purchase of machines capable of processing the biomass potentially usable as fodder in family farms, valorizing the construction of silos and thereby ensuring a stable source of animal feed during dry periods of the year; d) The ecological crops commission declared its opposition to the state government's initiative of compulsory spraying insecticides to combat the new pest attacking the region's *Citrus* plantations. As an alternative, it proposed conducting experiments with natural (non-toxic) products.

One of the strategic dimensions of the Pole's work involves converting these public resources into common assets to be continually mobilized by families in the operation of their farms. Since the behaviours and strategic decisions of farming families depend directly on the economic, sociocultural, institutional and environmental contexts in which their farms operate, the expansion and diversification of the base of locally available common assets considerably amplifies the room for manoeuvre of the families when it comes to conceiving and putting into practice strategies of endogenous development.

Analytically the territory functions as a socioecological system in which family agroecosystems are structurally coupled. The increase in the self-controlled base of common assets in the territory strengthens these links of structural coupling between the agroecosystems and the territorial suprasystem, enabling permanent flows of goods and services between the spheres of collective and private action, without implying the need for monetarized transactions, or the creation of dependency on externally-defined market rules. In this sense, the input of public

resources through negotiations established between the Pole and the State plays an essential role in the densification and intensification of the ecological, economic and social flows regulating the labour and processes involved in the production and distribution of wealth in the territory.

At the same time that it positions itself vis-à-vis the State as a political actor defending territorialized farming styles, the Pole (and its organizations) act to create and lend political-institutional support to decentralizing collective processes aimed at improving the governance and sustainable use of common assets indispensable to the agroecological intensification of agroecosystems. In this sense, the Pole functions as an incubator of local institutions intended to regulate the production and use of common assets and services by rural families and communities.

The Pole as an incubator of institutions[30]

A particularly decisive factor in the Pole's action as a driving force in rural development dynamics resides in the fact that its work focuses on supporting the creation and/or improvement of devices for collective action designed to manage common assets. These new devices, or institutional arrangements, can be seen to an emergence from the networks of farmer-experimenters activated by the pole: that is, as outcomes of the combined action of the social processes of local innovation and the mobilization of public resources through political action. Box 6 presents some of these devices for collective action.

Box 6: New institutional arrangements for managing common assets

1) Shared management of equipment: unions and associations belonging to the Pole have worked to organize the collective management of 10 mobile silage machines funded by the Territorial Development Program of the Ministry of Agrarian Development (MDA). These machines are used to produce silos, allowing the storage of cattle feed for use during dry periods of the year. The system for circulating the machinery is regulated by locally defined rules, associated with community work rallies that process the large volumes of fodder biomass produced by various plant species grown on family smallholdings. As well as allowing many families to make stockpiles of fodder in a short period of time, the system stimulates the planting of fodder species with the potential to be used as silage. This institutional arrangement benefits around 150 families with an average annual output of 10 tons of fodder. As well as the silage machines, a set of fruit pulpers is also managed by community work teams. These machines allow large volumes of native and exotic fruits to be processed for sale during the inter-

harvest season, playing an important role in stimulating the planting of fruit species. 2) Collective practices for preserving and reproducing biodiversity: a network of 65 seed banks ensures that the substantial agrobiodiversity heritage is conserved and made available for planting as soon as the rains start. As well as being adapted to local environmental conditions and crop systems, the passion seeds afford families greater autonomy and security in developing their crops. The network of nurseries used to produce tree saplings (forest and fruit species) is another initiative that has provided hundreds of families with access to a genetically diverse and high-quality material. Managed by unions and community associations, this network formed by six nurseries was developed as a system to reforest the farming landscape with multiple-use species. A network of forest seed collecting farmers was subsequently linked to the network of nurseries, stimulating the creation of a social group with knowledge and practical knowhow concerning the propagation of native tree species. To ensure the production of saplings, the organization of work in the nurseries very often makes use of work rallies (mutirão). 3) Community work rallies: as we have see in the previous items, this practice is very widespread in peasant farming regions, and is also used to construct small works for capturing, transporting and storing rainwater, which have been essential in terms of structuring a vast and interconnected water supply to meet the multiple demands of farming families. 4) Community savings and loans: a set of 90 Solidarity Revolving Funds (FRS) has been employed to enable the purchase of a variety of equipment and inputs needed to intensify the productivity of agroecosystems: water supply infrastructures, ecological ovens, screens for use in yards, manure, zinc silos, small livestock, etc. 5) Organization for accessing markets: a network of 8 agroecological fairs in the region's municipalities, as well as collective sale in institutional markets, especially via the Food Purchase Program (PAA) and the National School Meals Program (PNAE), enable the outflow of the diverse produce typical to family farming and an improved financial return on the work of the families involved.

Petersen et al. 2013

The emergence of these new devices for collective action created a new institutional environment in the territory, establishing a positive feedback mechanism with the dynamics of agroecological innovation by encouraging the circulation of goods and services between families and communities independent of market rules. A virtuous circle was generated, mutually strengthening human, social and institutional capital.[31]

From the analytic viewpoint, the core function of these new institutional arrangements is to stimulate beneficial connections and help produce synergies between different activities and actors in the territory, as well as between different levels in the multilevel system of territorial governance (Knickel et al. 2008). In this sense, these territorially-rooted institutions perform the role of catalyzing agents among actors on the same level – like the networks of farmer-

experimenters – and as mediators between higher and lower levels – like the agroecological fairs or the seed banks in relation to government policies and to farming families.

The intensification of social practices founded on reciprocity and mutual trust is another key element afforded by the emergence of these institutions. The transactions taking place through these practices are institutionally regulated at territorial level, mobilizing social and natural resources for economic production and reproduction independently of the commercial markets for inputs and services. Interpreted through the prism of the neo-institutional economy, these practices enable a drastic reduction in the transactions costs involved in the regional economic dynamics. In addition they enables improvements in terms of the scale and quality of these economic activities.[32] The case of the revolving funds used in the construction of slab cisterns is presented in Box 7 as an illustration of this phenomenon.

Box 7: The multiplication of effects by self-regulated institutions: the case of the dissemination of slab cisterns

The Solidarity Revolving Funds (FRS) are financing systems administrated by informal groups and/or community associations. Instead of directly funding the families, as occurs in the official banking system, the FRSs are composed of small groups that assume shared responsibility for managing financial capital. The revolving nature of the funds refers to the chain funding mechanisms through which each family benefits from the funds coming from the devolution of loans taken out earlier by other families. During the initial period of operation of the One Million Cisterns Program in Paraíba's Agreste region, the public funds allocated towards the building of the cisterns were used to set up the FRSs. In 2003 some 1,380 cisterns had been funded via this system, 656 of which had been built using financial resources repaid to the FRSs by the first families to receive the credit. This meant that the FRS mechanism enabled a 90% increase in the number of families benefitting from the funds originally allocated to the territory by the program. Taking into account, too, that the unit costs for the construction of the cisterns was reduced by an average of 30% due to the use of cooperative work by community members, we can calculate that the initial funds invested in the territory were multiplied by 172% due to the activities of institutions founded on reciprocity and cooperation. In other words: had the P1MC Program been implanted by a private company, the resources invested would have been sufficient for the construction of 506 cisterns at most.

Petersen and Rocha (2003)

The treasure map

The experiments being conducted in Brazil's semi-arid region reveals the importance of local actors as protagonists of rural development. A number of core ideas are essential to understanding the role of these actors and how they work, as well as the development trajectories driven by them. The first and most relevant of these ideas is that of immobilized local resources. These are the hidden treasures, as metaphorically described by one farmer from the Paraíban Agreste. They correspond to locally available environmental and social potentials that can be activated and developed by the processes of generating social wealth, but which more often remain concealed by the dominant forms of apprehending and intervening in the local reality. Consequently they fail to become integrated into the flows of economic production, rendering them superfluous insofar as they become squandered in the socioecological metabolism.[33]

The second key idea is that of peasant farmer innovation, a social process defined here as the identification, experimentation, evaluation and interconnection of locally available resources within the territory's economic systems. Farmer innovation unfolds through the continual learning of practices capable of altering pre-existing work routines, responding to problems and obstacles experienced locally by rural families and communities. In the experience described here, the agents of farmer innovation are farmer-experimenters. Setting out from the identification of a problem, a farmer-experimenter is someone who has an idea about the cause of this problem and decides to test a way of solving it through the use of locally available resources. It is, therefore, a process of experimentation just as formal as the most systematic scientific research (Hocdé 1999).

The dynamics of peasant innovation evolve through the continuous learning enabled by consistently connecting the lessons learnt through the action of the farmer-experimenters. In the present case, this horizontal interconnection between the actors involved in farmer innovation is expressed through the notion of a network of farmer-experimenters, the third key idea.

The networks of producing and sharing knowledge founded on farmer innovation are structured and dispersed through specific sociomaterial realities in which local resources are identified, mobilized, interconnected and developed. These realities are expressed at various geographic scales, which correspond to distinct levels of socio-organizational aggregation. The

upper scale is the space delimited by the reach of the farmer-experimenter networks. This space corresponds to the rural territory – the fourth key idea – a scale where local resources are present in the form of common assets, both material and immaterial. The new institutional arrangements – i.e. devices for collective action – designed to regulate socially the management of common assets are the main products of farmer innovation at this scale.

The lower scale corresponds to the family farm, the private space of farmer innovation. This space is that of the agroecosystem – the fifth key idea – a scale economically managed by the farming families themselves. At this sphere of activity, the local resources are identified, mobilized and recombined on the basis of productive strategies experimented at the initiative of individuals and/or families. At this scale, the novelties at a technical level are the main products of farmer innovation. These are essentially designed to valorize the ecosystem's abiotic resources – water, nutrients and solar radiation – by integrating them into ecological cycles through biodiversity management. By employing this strategy of valorizing ecological capital, peasant innovation promotes economic intensification without ecological simplification, in the process developing more productive agroecosystems less dependent on external inputs.

The private and collective contexts in which peasant innovation occurs are not particularly clearly defined given that a mutual interdependence exists between both spheres. As family management units, the agroecosystems are conditioned by the transformations to the institutional arrangements that occur at higher spheres, just as the evolution of the territory as a socioecological system is a direct outcome of the transformations taking place at the level of the agroecosystems run by farming families. Analytically speaking, the agroecosystems and the territory establish an autopoietic relation – that is, a relation of coproduction between systems interconnected at distinct hierarchical levels.[34] Taking concepts from the theory of autopoiesis, we can say that the operational closure of agroecosystems depends on their structural coupling with the territory.

The grammar of peasant innovation is structured, therefore, through the use and development of the immobilized local resources, configuring a strategy geared towards the continuous expansion of the room for autonomy from market-based rules imposed from outside. In place of the growing dependence on financial capital generated by the trajectories of agricultural modernization, farmer innovation is based on the mutual valorization and strengthening of human, social, institutional and ecological capital present in rural territories. These are the

hidden treasures that, when seen in a integrated way, make up territorial capital (Ventura et al. 2008).[35]

The comprehension of the multifaceted, multidimensional and multilevel nature of territorial capital implies understanding the agricultural reality through a systematic approach focused on the rural territory and the agroecosystems structurally coupled to them. In other words: territorial capital is the outcome of a specific complex reality and can only be discerned and valorized in trajectories of endogenous development when apprehended in the context of the socioecological system that produced them. Groucho Marx expressed this idea with these simple words: "Shall we discover some treasure in that house? – But there isn't any house… – So let's build one!"

The study (logos) of the house (oikos) forms the object of Ecology, which, applied to the study of agrarian systems, can be specifically termed Agroecology. This emphasizes the central importance of the use of an agroecological perspective – the sixth key idea – as part of the process of building knowledge of the agricultural reality of Paraíba's Agreste region. With the advisory of AS-PTA, the reality of the territory and the diverse forms in which its agroecosystems are shaped have been studied through participatory diagnoses and the systemization of the results of farmer experimentations in the context of farmer-experimenter networks. AS-PTA also plays a decisive role in the mediation between the Pole and academic institutions, mobilizing knowledge from many scientific disciplines as a way of enriching the cognitive capital (Dowbor 2011) that circulates in farmer-experimenter networks.

The agroecological approach employed in the process of producing and sharing knowledge also generates a strategic coherence to the forms in which the farmer-experimenter networks conceive reality and intervene in it. This coherence is produced through the inter-relation between lived, perceived and conceived spaces (Halfacree 1993, quoted in Ventura et al. 2008). Lived space corresponds here to the realm of practices, perceived space to the realm of knowledge and conceived space to the system of values, or ideology, that frames the visions and divisions of reality (ibid).[36]

In this sense the shift from the notion of combatting the drought to living with the semi-arid is a manifestation of the construction of a new strategic coherence that favours the repositioning of local actors vis-à-vis their reality. In turn, this repositioning impacts on the construction of

the political capital of the Pole (and ASA) through the promotion of a rural development project based on the paradigm of living with the semi-arid – the seventh key-idea

This indeed is how the Pole has presented itself in different spheres of political negotiation with public bodies. Its action at this level can be defined as the fight to increase territorial capital. From this viewpoint, the public funds allocated by State policies and programs reach the territory to increase the self-controlled base of resources, thereby amplifying the degree of autonomy involved in the unfolding trajectories of endogenous development.

In a context dominated by the modernization paradigm, this shift in perspective concerning the role of the State vis-à-vis civil society organizations manifests as an enormous political challenge. This challenge is expressed both in the design of the public policies executed by governments, and in the legal frameworks that regulate the access to and use of public funding by civil organizations.

The position of the Brazilian State concerning the experience of disseminating the slab cisterns described in this chapter provides a clear indication of the challenge to be met in order for the paradigm of agricultural modernization to be superseded in theory and practice, so that the State includes the treasure map within its strategies for promoting rural development.

Seeds versus herbicides[37]

Despite the unequivocal demonstration of the efficiency and effectiveness of the software developed for the implantation of the slab cisterns for the P1MC Program, the State has demonstrated a failure to assimilate its multifaceted nature and its systemic implications for the dynamics of rural development.

At first sight this is somewhat incomprehensible. The federal government proposed a massive program offering tens of thousands of new water cisterns to the semi-arid region. This was presented as an ‘acceleration’ of the civil society initiatives discussed in this chapter.

In order to understand this confrontation it is important to go back to the cistern hardware and software developed by the bricklayer Nel and later widely disseminated under the aegis of the ASA. The ‘Nel’ type of cistern is made of concrete and iron. It is constructed by local bricklayers and built with materials bought on local and regional markets. Thus the cistern was

indeed able to function as a seed of change. It strengthened the local economy and increased employment. It also allowed for flexibility. The cistern could be designed and scaled according to local conditions, needs and possibilities. The installation required excavation (a laborious task given the rocky subsoil found in the semi-arid region). This was resolved with voluntary labour based on reciprocity. Here again the cistern functioned as a 'seed.' It strengthened the social capital in the area. Likewise new institutional arrangements were introduced, like the 'revolving funds.' The implantation of the P1MC Program through revolving funds, in turn, was prohibited due to the absence of an appropriate legal framework. The funds were considered an irregularity subject to legal penalties.

Above all the cistern and the associated method (or 'software') generated the conviction among the local population that they themselves could contribute strongly to the development of the region. Development was not necessarily a 'gift' that came from elsewhere (i.e. from the benevolent state or from regional governors operating a system of clientelism) – it could be constructed, instead, very adequately by local actors themselves. Thus a new 'political field' was opened and strengthened.

Compared to the 'Nel type' of cistern, the government proposal was very different. The new cistern is not made in situ but industrially and out of plastic (polyethylene). Thus the flexibility of adapting the cistern to local conditions is lost, just as the additional employment for local bricklayers is eliminated. Needless to say, the raw materials needed for the new cisterns cannot be acquired in the region itself. The 'software' also changes. Everything is paid for by the State. Voluntary labour, revolving funds and so on are all features that become redundant. Ironically this makes the 'new' cisterns more expensive than the former 'Nel-type' ones. Thus the 'seed' nature of the initial novelty is completely lost. The 'new' cisterns are an artefact introduced from the outside (typically it is an expression of exogenous development). They no longer translate into new, additional activities and effects that together constitute a process of self-driven and self-controlled development. The 'new' cistern again turned 'development' into a blessing coming from elsewhere.

Among the social movements participating in the ASA framework, the 'new' cistern and the associated program were immediately understood as an expropriation – not only of 'their' cistern but above all of the political space that had been constructed in such a well-balanced way. Instead of functioning as a seed, it acted on the social process like a herbicide.

This was the reason why ASA organized large-scale protest to the project of deconstruction announced by the federal government. As the most visible expression of this resistance, 15,000 farmers from all parts of the semi-arid region travelled to the town of Juazeiro, Bahia, in December 2011 to demonstrate in the streets and express their dissatisfaction. This demonstration of collective strength led the government to negotiate its position. Since then we have seen the coexistence of P1MC, a program that seeds new horizons for living with the semi-arid region, with the program implanted exclusively by government apparatuses, responsible for reinforcing practices that lead to social demobilization.

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Notes

[1]. As well as reducing the unit cost of a 16,000 litre cistern from U$ 690 for U$ 240, the equipment invented by Nel has a cylindrical format, eliminating the corners of the vertical walls that formed weak points where the cracks and infiltrations frequently developing in brick cisterns would begin to appear (Petersen and Rocha 2003).

[2]. Training and Mobilization Program for Living with the Semi-Arid Region – One Million Rural Cisterns – P1MC. Years later ASA inaugurated the One Land and Two Waters Program (P1+2), focusing on the implantation of small rainwater capture and storage infrastructures for use in food production.

[3].To mobilize the resources needed for this enterprise, ASA established partnerships with the federal government, private companies and international cooperation agencies.

[4].See www.asabrasil.org.br

[5]. From 2003 to January 2014, P1MC had built more than 510,000 cisterns, benefitting more than 2,250,000 people. The program won national and international awards recognizing its impact on improving the quality of life in Brazil's semi-arid region. These awards included the 2010 Human Rights Award, given by the Presidency of the Republic, and the Seeds Award, given by the United Nations (UN) (ASA 2014).

[6]. Institutional design is a proposal developed by the neo-institutionalist school of thought, which argues that social action is the outcome of the interaction between individuals through the intermediation of their institutions and between institutions themselves.

[7].The drought industry is a term used to designate the strategy employed by certain social groups to benefit from the large volumes of resources and advantages offered by the drought fighting policies in the Brazilian semi-arid region.

[8].This subtitle is the slogan adopted by the Brazilian Semi-Arid Alliance (ASA) and reflects its strategy of deconstructing the collective imagery related to the determinist rhetoric ideologically sustaining the idea of combatting the drought.

[9].The modernization project was only implanted in small areas of the semi-arid region that possessed the appropriate environmental conditions for reproducing intensive styles of farming, based on an economy of scale and regulated by globalized markets, led by the tropical fruit market. The access to water springs for the installation of large intensive irrigation projects is the main precondition for establishing this style of production. To render the system viable, the State invests huge financial resources in the installation of the infrastructure required to capture, store and transport the water.

[10]. The constitution of regional and/or state networks is a feature of the organizational process of the Brazilian NGOs identified with the agroecological field. The regional networks (which

include ASA) are connected to social movements (also national and regional in scope) to form the National Agroecological Alliance (ANA), a national-level network of networks.

[11] Excerpt from the *Declaração do Semiárido*, a document elaborated by the civil society organizations assembled in 1999 during the Parallel Forum to the 3rd Conference of Parties to the United Nations Convention to Combat Desertification..

[12] Excerpt from the *Political Charter of the 4th National Encounter of ASA* (2003), held in Campina Grande.

[13] Seeds of *Transition* is the apt metaphor coined by Wiskerke and Ploeg (2004) to characterize the emergence and consolidation of novelties in endogenous dynamics of rural development.

[14] The notion of strategic niche management derives from a multilevel theoretical perspective. According to the latter approach, technological transitions are explained by the inter-relation of processes at three different heuristic levels: the analytic concepts of innovation niche, technological regime and sociotechnical landscape. Niches represent the local level of innovation processes and are commonly referred to as protected or incubatory spaces in which new technologies or sociotechnical practices emerge and develop in isolation from the normal market pressures or systems. The technological regime is characterized by stabilized products and widely accepted technologies, stores of knowledge, use practices, protocols, techniques, expectations, norms and regulations (Kemp et al. 1998; Geels 2005 cited in Marques 2009).

[15].The term s*ertão* originates from the word *desertão* (i.e. big desert) and was used by Portuguese colonizers to describe their perception of the physiognomy of the interior region, marked by the presence of Caatinga vegetation (white forest in the Tupi language) typical of the Brazilian semi-arid conditions, especially in contrast to the coastal region, occupied by dense tropical rainforest.

[16]. Indeed the region has been the setting for peasant struggles that date back to the colonial period. The current processes of resistance cannot be understood, therefore, without taking into account the history of these struggles (Silveira et al. 2010).

[17]. In her classic work, Boserup (1981) showed that changes to the technological base of farming were frequently induced by a reduction in the environmental resources available to sustain the local population, especially arable land. Increases in population density leading to land scarcity functioned as triggers unleashing dynamics of sociotechnical innovation towards agricultural intensification. One of the main conclusions of Boserup's work is that there is no agrarian ceiling or natural support capacity within any particular region. Productivity levels depend not only on ecological capital but also the social and human capital capable of continually improving technical systems through investment in local experimentation.

[18]. AS-PTA – Family Farming and Agroecology (www.aspta.org.br) is a national-level NGO that since 1993 has maintained a program providing advice and assistance to family farming

organizations in the Agreste region of Paraíba with the goal of supporting their role as collective actors central to the dynamics of rural development.

[19]. The understanding of the role of peasant farmer rationality in agricultural intensification opened up new perspectives for the development of the science of Agroecology from the 1980s onwards (Gliessman 1998). Since then Latin America has seen an upsurge in the creation of NGOs dedicated to advises dynamics of rural development driven by peasant organizations through the employment of the agroecological approach.

[20].The social process of constructing structured coherences between the natural and social environments with the aim of capturing flows of resources has been called *territorialization*. The idea of a network is a metaphor increasingly used to describe and explain these processes of territorialization (Ventura et al. 2008).

[21].The notion of the farmer-experimenter was assimilated following an exchange trip to Central America held in 1997, in which technicians from AS-PTA and union leaders were able to learn about the *Movimento Campesino a Campesino* in Nicaragua, in particular its mechanisms for institutionalizing collective dynamics of agricultural innovation via the proactive engagement of farmers and their organizations. The Regional Program for Reinforcing Agronomic Research on Basic Grains (PRIAG in its Spanish acronym), linked to the Inter-American Institute for Cooperation on Agriculture (IICA), was also visited during the same trip. Coordinated at the time by the French agronomist Henri Hocdé, PRIAG was attempting to shift beyond the farmer-to-farmer dynamic by stimulating interaction with official research institutes from the six Central American countries. The notion of the farmer-experimenter was used by Hocdé (1999) to redefine roles and identities of the farmer vis-à-vis those of the technical researchers and extensionists working in the official systems.

[xxli]. A similar situation is described by Ploeg (2008) in the case of territorial cooperatives in the north of Holland, which, the author proposes, function as *field laboratories*.

[23].The findings are available at www.cpatc.embrapa.br/publicacoes_2012/doc_179.pdf (consulted on 12/02/2014).

[24].The results of this process were decisive in ensuring the federal government's commitment to back the creation of a support program for community seed backs in the semi-arid region, executed by the Brazilian Semi-Arid Alliance. This program, scheduled to begin in 2014, forms part of the National Plan for Agroecology and Organic Production and aims to build hundreds of seed banks in the rural territories where ASA runs its programs to promote water security.

[25].In this sense the genotypes of local varieties are carriers of biological and cultural messages, making them products of human-nature coproduction (Petersen et al. 2013).

[26]. The production of maize straw for cattle feed, for example, is a criterion highly valued by farmers from Brazil's semi-arid region. Varieties that produce little straw, such as the *Catingueiro* maize distributed by government programs across the entire semi-arid region of

Brazil, due to its extreme precocity (and higher chance of production in low rainfall), have been questioned by farmers. Varieties with dual purposes (used to produce both grain and straw) tend to be more valued in these production conditions. This example reveals the lack of a systemic perspective in the implementation of conventional agronomic research and the importance of the dialogue between knowledge practices for research to be adequately contextualized and conducted, with the aim of reinforcing the complex and singular strategies of production and reproduction pursued by family farming.

[27] The concept of farming styles proposed by Ploeg (1994) derives from a theoretical-methodological approach that has proven to be extremely useful and versatile in describing and interpreting the diversity of contemporary farming. One of the central elements in this proposal is distinguishing between different styles on the basis of the degree of autonomy (or dependence) in relation to the market and access to technologies. The construction of styles as a tool for representing agricultural diversity involves the identification of varied forms of organizing the social and material resources used in the context of production units, without losing sight of the relations established with outside agents (financial institutions, input suppliers and product buyers, technical advisory services, etc.).

[28] The Pole acts as an institutional mediator with public bodies operating at different federal levels and managing different resources: municipal, state and national governments, the Territorial Development Committee (a body linked to the territorial development policy of the Ministry of Agrarian Development). It also works to mobilize resources from international cooperation.

[29] The experience developed by the Pole inspired the creation of a state network in defence of passion seeds, institutionally coordinated by the Paraíba Semi-Arid Alliance (ASA-PB), the branch of ASA Brazil in Paraíba state. The state seed network holds annual meetings, bringing together thousands of farmers in defence of public policies aimed at promoting and conserving agrobiodiversity. A state law supporting community seed banks was created as a result of the political campaigning of ASA-PB. This experience in turn inspired the formulation of a program for the entire Brazilian semi-arid region, set to be implemented in 2014 as one of the measures of the National Plan for Agroecology and Organic Production (Planapo).

[30] Institutions can be understood as structures and mechanisms of social configuration and cooperation that govern individual behaviour. They can also be comprehended as sets of regulations, laws, norms and traditions shaped through social interactions (North 1990, quoted in Knickel et al. 2008).

[31] As Knickel et al (2008) point out in reference to the dynamics of rural development in Europe, the interaction between the institutional dimension and social capital is significant since regions with higher levels of social capital are better prepared to create and adapt new forms of organization.

[32] Ploeg (2008: 67) calls attention to the fact that even when money is no impediment to the realization of economic exchanges, "reciprocity is extremely advantageous when compared with the market alternative, especially because it functions as a mechanism for maintaining the quality" of the work. This applies to the process of cistern building through community work rallies compared to their construction by private companies contracted by the government.

[33] The original idea of a metabolism in the relation between nature and society came from an insight first made by Karl Marx (Foster 2011) and subsequently developed by ecological economists. Seen through the notion of socioecological metabolism, the economy is envisaged as an organism that collects resources from outside and later discards residues.

[34] Developed by the Chilean biologists Humberto Maturana and Francisco Varela, the Theory of Autopoiesis, or New Systemic Theory, postulates that the living system is structurally connected to its environment through recurrent interactions, each of which unleashes structural changes in the system (Maturana and Varela 1995; 1997). I have argued elsewhere that the agroecosystem, as a basic management unit in peasant farming, can be apprehended as the expression of a technical-economic strategy focused on valorizing the resource base that the farming family can deploy to attain its objectives, using specific patterns of operational closure and structural coupling with the rural territory (Petersen 2011).

[35] The meaning of the term capital has gradually expanded in the social sciences as part of the attempt to explain growing differentials between regions that, in theory, possess the same capital when measured in a conventional form. In this expansion of the concept, capital took on various forms: human, social, economic, cultural, symbolic and natural (Bourdieu 1985, quoted in Ventura 2008). Territorial capital is composed of a stock of resources specific to the territory (both material and immaterial) that are available to be mobilized by those living and working in the territory in the realization of their projects (Ventura et al. 2008).

[36] "These three dimensions are strongly inter-related. Practices connect social representations with material components of space and are affected by cognitive frameworks of the actors. A plant can be thought of as a weed or as a useful plant, not only because of its characteristics, but also because of the knowledge of its users. In turn knowledge is strongly affected, and more often distorted, by ideology. At same time, reflecting on practices may cause adjustments of cognitive schemes and systems of values" (Ventura et al. 2008: 155).

[37] My thanks to Jan Douwe van der Ploeg for collaborating in the development of this section.

3.5 – Artículo 5 – Agroecology, Public Policies and Labor-Driven Intensification: Alternative Development Trajectories in the Brazilian Semi-Arid Region

Referéncia

Petersen, P., e Silveira, L.M. 2017. "Agroecology, Public Policies and Labor-Driven Intensification: Alternative Development Trajectories in the Brazilian Semi-Arid Region". Sustainability 9 (4): 535. doi:10.3390/su9040535.

Abstract

The institutional recognition obtained by family farming in Brazil over recent decades has translated into the launching of a broad and diverse set of public policies specifically aimed towards this sociopolitical category. However, the design of these policies was heavily influenced by the productivist bias derived from the agricultural modernization paradigm, making the sector increasingly dependent on input and capital markets. In this same movement of institutional evolution, policies consistent with the agroecological approach created new margins for maneuvering for development trajectories founded on the use of local resources self-controlled by rural families and communities. Taking as a reference the recent trajectory of rural development in Brazil's semi-arid region, the article analyses the role of the agroecological perspective in the strategic combination between territorially endogenous rural resources and public resources redistributed by the State. Based on the analysis of the economy of agroecosystems linked to two sociotechnical networks structured by contrasting logics of productive intensification, the study demonstrates agroecology's potential as a scientific-technological approach for the combined attainment of various Sustainable Development Goals, starting with the economic and political emancipation of the socially most vulnerable portions of the rural population.

Keywords: rural development; agroecology; agricultural intensification; public policies; sociopolitical innovation

1. Introduction

The quarter century spanning from the beginning of Brazil's return to democracy, especially following the proclamation of the 1988 Constitution, and the abrupt end of the Dilma Rousseff government in 2016 marked a period of innovation in the institutions linked to rural development in the country. One decisive element in this process was the inclusion of the family farming in the 'social pact', which authorized the launch of public administration policies and instruments targeted specifically at this sociopolitical category, previously pushed to the margins of the Brazilian State's interests.

These institutional advances, which brought Brazil widespread recognition during the International Year of Family Farming in 2014, should be understood as the end result of a long historical trajectory of struggles and demands pursued by rural social organizations and movements (Grisa e Schneider 2015). The core point of this struggle for social recognition and legitimization is the affirmation of the specificities and potentialities of the modes of production and ways of life of this extremely diverse social universe as part of resolving an interconnected set of polarizing questions about the national public agenda: the rise in unemployment rates; the continuing rural exodus and the growth in unplanned urbanization; increasing levels of urban violence and rural conflicts; the rapid degradation of ecosystems; the crises in the food supply and, as a consequence, the elevation in inflation rates and in the population's levels of food and nutritional insecurity.

The launch of the National Program for Strengthening Family Farming (Programa Nacional de Fortalecimento da Agricultura Familiar: PRONAF) in 1995 was a landmark for the official legitimization of family farming. However, it was only from 2003 onward, with the political priority given by the Lula government to eradicate hunger in the country, that a broad and diverse set of official initiatives created an institutional environment more favorable to development and to the public expression of the family farming's contribution to society as a whole.

In the course of this instituting process, the launch of the Zero Hunger Program, the inclusion of the Human Right to Adequate Food (HRAF) in the Federal Constitution, and the approval of food and nutritional security plans (PLANSAN) and plans for sustainable and solidary rural development (PNDRSS) contributed to strengthening the conceptual and political connection between the official initiatives aimed at strengthening family farming and the strategies for

overcoming rural poverty and promoting food and nutritional security in the country. New institutional arrangements created during this period generated synergetic effects between social welfare initiatives and economic development programs, two spheres of intervention historically autarchic within the State's functional structure.

According to the multilevel perspective approach (Geels 2002; Wiskerke 2003), these advances that were made can be understood as niches of institutional innovation in a political-ideological environment dominated by a narrative that asserts the supposedly inherent incapacity of impoverished small farmers to adapt to the technological and financial treadmill of modern farming (Buainain et al. 2014).

Rooted in earlier theoretical approaches that questioned the economic propensity and social reproductive capacity of the poorest contingent of the rural population (Shultz 1965; Paiva 1986), this dominant narrative continues to assert homogenization of the rural world as an inexorable process. For theorists linked to this approach, most of the family farming sector, branded as peripheral, is destined to vanish. Family farming policies should therefore focus exclusively on those sectors identified as consolidated and in transition (Food and Agriculture Organization/Incra 1994), perceived as the legitimate agents of social and economic progress in the rural world.

According to this prevailing narrative, rural development is driven by the economic growth of farming establishments, envisaged as independent business units. This growth, in turn, is viewed to be an outcome of trajectories of productive intensification promoted by the use of modern technologies. Through this rhetorical construct, rural development was equated with agricultural development and the latter with the modernization of the technological base of agroecosystems. Consequently the very concept of intensification became unduly assimilated as a synonym of technological modernization. As a corollary, alternative trajectories of economic intensification, built using the multifunctional potential of family farming, were excluded from the horizon of possibilities propagated and legitimized by the dominant narrative. Consequently the interpretative schemes based on the modernization paradigm used to interpret the agrarian world, and which strongly influence the design of agricultural and agrarian policies, are incapable of recognizing, describing, and analyzing rural development trajectories that are essentially driven by family farming labor.

The State initiatives consistent with the agroecological paradigm should be understood and evaluated within this political-ideological and institutional context. Exploiting the limited institutional spaces achieved with governments more permeable to democratic debate, organizations from the agroecological field were able to take the lessons learned from decades of decentralized construction of agroecology among rural communities, transforming this social experience into innovative public policy proposals. The evolution of this process culminated in 2012 with the creation of the National Policy for Agroecology and Organic Production (PNAPO), put into operation in 2013 by the First National Plan for Agroecology and Organic Production (I PLANAPO), which was updated and revised in 2016 in Plan II (Paulo Petersen, Mussoi, e Dal Soglio 2013).

The growing participation of grassroots movements seeking to establish themselves in the public spaces in which government policies are formulated and monitored (Fressoli et al. 2014) created conditions favorable to rural development dynamics consistent with the agroecological approach. Previously driven almost exclusively by territorial-level civil society networks, these dynamics began to receive substantial support from government funding. Contrary to the direction taken by agricultural modernization policies and programs, the public funds invested in these trajectories helped increase social capital and ecological capital in rural territories, stimulating the expansion and diversification of these sociotechnical networks through an endogenous development approach (van der Ploeg 1994) Two interrelated ideas are central to the concept of endogenous development: local resources and local control. In this sense, the endogeneity of development is determined by the degree to which rural economies are: (a) constructed on the basis of local resources; (b) organized in accordance with local models of combining resources, which also implies control of the use of these resources; (c) strengthened through the distribution and local reinvestment of locally produced wealth (Oostindie et al. 2008)).

In economic terms, these endogenous trajectories are guided by a model of labor-driven intensification (van der Ploeg 2008). This signifies that instead of the intensive support of market-supplied factors of production, a characteristic typical of conventional trajectories of agricultural intensification, the agroecological approach is based on the use of skilled labor (Timmermann e Félix 2015) to promote ecological processes at the level of the landscape, simultaneously ensuring the continuous regeneration of ecosystem services (Tittonell 2013) and the conversion of natural goods into a diverse range of economic goods.

Taking as a reference point the recent dynamics of rural development in the Brazilian semi-arid region, a process promoted by a new generation of public policies, this article seeks to show how the strategic combination of resources endogenous to rural territories and public resources redistributed by the State has favoured the unfolding of agricultural intensification trajectories that organically articulate economic production with ecological reproduction. In this sense, these trajectories differ fundamentally from the controversial notion of sustainable intensification (TheRoyal Society (London) 2009) that became integrated into the new official rhetoric in international debates about the future of farming and food, without challenging the technicist and productivist bias inherited from the narrative of agricultural modernization. As González de Molina and Gúzman Casado emphasize, and as formulated and disseminated, this notion amounts to a contradiction since it lacks any thermodynamic basis concerning the sustainability perspectives of agroecosystems (González de Molina e Guzmán Casado 2017).

The study also looks to show how public support for these trajectories of economic intensification without ecological simplification (P. Petersen, Silveira, e Galvão Freire 2012) can help overcome the structural poverty in which the majority of the rural population is trapped, as well as engaging poor family farming as dynamizing agents of rural development capable of generating wider benefits for society, contributing to the combined attainment of various Sustainable Development Goals (SDGs) (United Nations 2015).

2. Material and Methods

2.1. Context of the Study

Measured in territorial or demographic terms, the Brazilian semi-arid region is one of the largest such regions on the planet. Covering a geographic area of 982,000 km2, concentrated in states in Brazil's Northeast, the region is home to a population of 22.5 million—12% of the national population—with 44% living in the rural area, making it the least urbanized region of the country (Instituto Brasileiro de Geografia e Estatística 2010).

Also concentrating 35% of the country's family farming establishments (1.5 million) (Instituto Brasileiro de Geografia e Estatística 2009) and more than half of the country's poorest population (Instituto Brasileiro de Geografia e Estatística 2010), the Brazilian semi-arid region is considered a problem region in some intellectual and political circles (Carvalho 2014). This kind of interpretation reflects a determinist bias that associates, as though two sides of the

same coin, the low social indicators with the recurrent droughts typical of the biome's semi-arid conditions. The narratives historically produced through this bias imposed themselves on the national collective and political imagery, generating an environment of tacit acceptance of a supposed historical predestination of the region to poverty and backwardness compared to other regions of the country. For decades the dissemination of this fatalistic view of the historical process in the semi-arid region exerted a strong influence on the legitimization of the system of power responsible for maintaining the extremely concentrated agrarian structure inherited from Brazil's colonial era (Furtado et al. 1998). Because of these structural conditions, family farming emerged and developed in the region on the margins of the large estates dedicated to extensive cattle ranching.

The long history of territorial dispute with big landowners and the increasing constraints on land, an outcome of the fragmentation of family establishments caused by intergenerational processes of dividing up inheritances, left traditional strategies for managing the fertility of agroecosystems increasingly out of step and vulnerable. The high levels of migration away from rural areas, especially among young people, highlight the significant limitations posed to the social and economic reproduction of family farming in the region.

In parallel with the demographic exodus, however, family farmers, individually or collectively, sought to develop technical-economic and political responses to the agrarian issue in the region. These responses combine two simultaneous movements: on one hand, the fight for land; on the other, the innovation in agroecosystem management practices designed to intensify the use of agricultural land (P. Petersen, Silveira, e Almeida 2002). Though largely invisible, this second movement corresponds to a recurring process of change to the technological base of peasant agriculture when faced with limited access to natural resources, beginning with the land (Boserup 1981) One of the main conclusions of Boserup's work is that there is no agrarian ceiling or natural support capacity in any particular region. The levels of productivity obtained depend not only on ecological capital but also on the social and human capital capable of continuously improving technical systems through local investment in experimentation (Boserup 1981).

Founded on the contemporary paradigm of living with the semi-arid region (Silva 2006; Conti e Pontel 2013) in contrast to the established notion of fighting the droughts, this decentralized movement of peasant innovation has been responsible for the development of an extensive

stock of technologies and management processes relating to production and social organization, adapted to the very specific edaphoclimatic and agrarian conditions of the semi-arid region. For a long time, though, this innovation remained largely unnoticed and/or shunned by public programs aimed at regional development.

It was only from the 1980s onwards with the return to democracy in Brazil that civil society institutions became structured to provide systematic advice to peasant organizations (P. Petersen e Gomes de Almeida 2007), looking to associate the critique of the historical pattern of agrarian occupation in Brazil and of the conservative modernization project (Graziano da Silva 1983) with the building of alternative styles of rural development.

Identified today with the agroecological field, these civil organizations work in an integrated fashion with the decentralized dynamics of rural development in the region. At the end of the 1990s, after almost two decades of accumulating practical experiences, the organizations united in the Brazilian Semi-Arid Alliance (Articulação Semiárido Brasileiro: ASA). Today ASA comprises a network formed by more than a thousand organizations present in the eleven federal states covered by the semi-arid region, (see www.asabrasil.org.br) drafted and advocated for public programs for improving water security in rural communities. ASA was responsible for designing, negotiating, and executing two programs for improving water security: the Program for Training and Mobilizing to Live with the Semi-Arid Region—A Million Rural Cisterns (P1MC), designed to ensure quality water for human consumption; and the One Land and Two Waters Program (P1 + 2), aiming to install local infrastructures for catching and storing rainwater for food production. Fifteen years after the launch of ASA's programs, more than one million and two hundred thousand cisterns for human consumption (first water) and more than 160,000 infrastructures for storing water for production (second water) have been implanted (MDSA 2016).

The infrastructures implanted by the public programs run by ASA allow the capture and storage of rainwater, reducing a critical ecological factor in the region's agroecosystems. Consequently they play a decisive role in expanding the margins for maneuvering for the development of trajectories of local innovation rooted in the recombination of other elements from the resource base self-controlled by rural families and communities, whether such elements are material (land, biodiversity, infrastructure, etc.) or social (labor, knowhow, cooperation practices, etc.).

Analytically, ASA's programs reproduce practices and perspectives consistent with the notion of endogenous rural development, a pattern of development founded on the deployment and redynamization of resources locally available in rural territories (Ploeg 1994). Among other characteristics, this pattern reactivates ecological capital and expands social capital through trajectories of technical and socio-organizational innovation driven by territorial-level sociotechnical networks.

As social constructs, these agroecology sociotechnical networks vary from place to place in terms of the levels of governance that they exert on rural development dynamics. On one hand, this governance is related to the capacity of actors linked to the network to combine the public resources mobilized through different policies in line with a specific strategy focused on the quantitative and qualitative expansion of the self-controlled resource base. On the other hand, it entails the capacity to involve, commit, and mobilize the participation and political support of growing sectors of the rural and urban population, seeking to amplify the room for maneuvering so that the network can spread horizontally and increase in density within the territory.

This second aspect is essential, especially when we consider that agroecology networks are not formed in territories free of disputes over endogenous resources and the allocation of public resources. Sociotechnical networks structured by technical-economic approaches informed by the modernization paradigm also channel public resources to the territories, very often by means of the same policies, but establish distinct and frequently conflicting forms of appropriating ecological assets and organizing the agricultural labor process.

By employing public resources redistributed by the State predominantly to the expansion of the self-controlled resource base at the level of the agroecosystems and rural communities, the agroecology networks help strengthen the territorial economies through investment in qualified labor informed by contextualized knowledge (Timmermann e Félix 2015). In summary, the issue is one of catalyzing development trajectories rooted in distribution and local reinvestment of socially produced wealth, contrasting with the conventional dynamics of economic growth, founded on the systematic (and growing) influx of capital and exogenous technologies.

The recent experience in the Brazilian semi-arid region exemplifies the importance of the agroecological perspective in the establishment of mechanisms of synergetic coordination between public policies, in order for their resources to be channeled coherently in endogenous development trajectories.

In order to assess the potential impacts of this emergent process in the semi-arid region, the study focused on the Borborema territory, a region in the state of Paraíba densely occupied by family farmers producing staple foods and an area where a vigorous sociotechnical network inspired by the agroecological paradigm has been developing for more than twenty years. Supported by the non-governamental organization AS-PTA (www.aspta.org.br), this network is dynamized by the Polo Sindical e das Organizações da Agricultura Familiar da Borborema (Pole)—a collective actor that currently connects 14 municipal-level rural workers unions, 150 community-level grassroots organizations, and a regional association of agroecological farmers, Ecoborborema (Petersen e Silveira 2006),(Silveira, Freire, e Diniz 2010).

The network expanded and spread further afield with the decisive input of public funds mobilized through a broad and diverse set of government policies. Today it mobilizes a social base of around five thousand farming families, corresponding to roughly 30% of the family farming universe in the territory's 14 municipalities. Organically integrated with the network, a movement of women farmers has grown in strength, participating actively in the local dynamics of agroecological innovation and in the fight against gender inequalities.

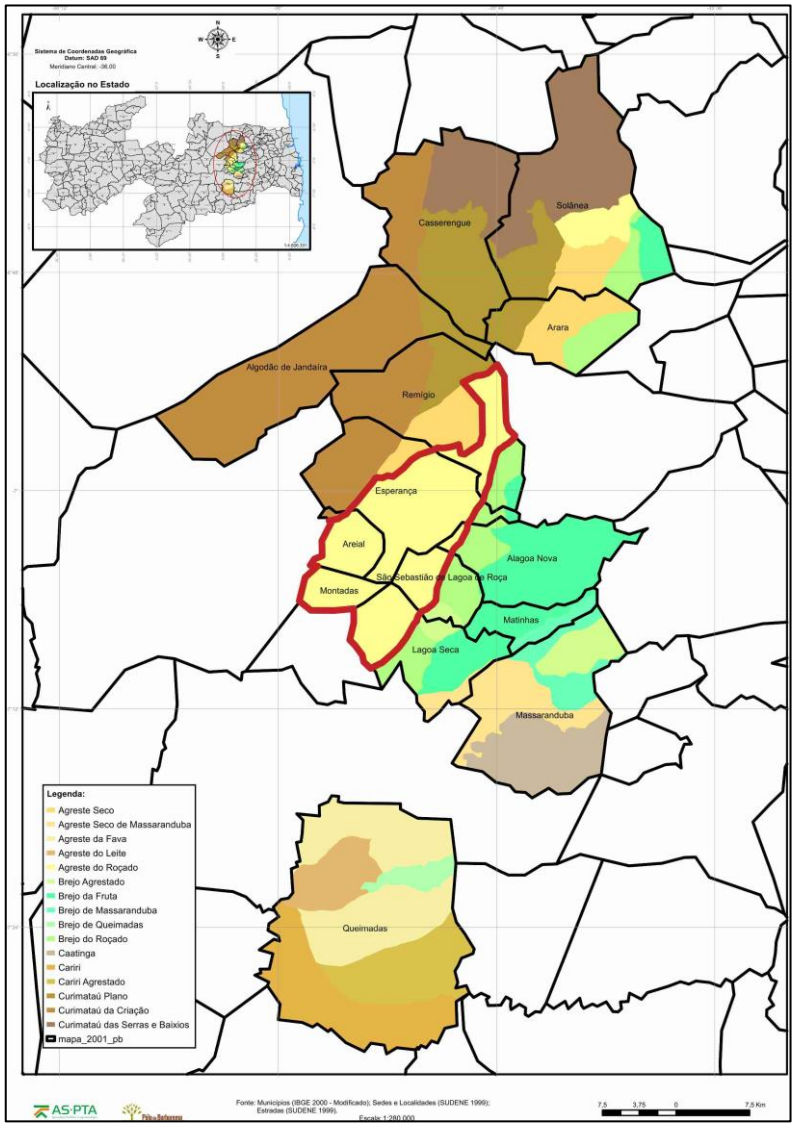
2.2. Characterization of the Heterogeneity of Family Farming in the Territory

At the outset of its work in the region in 1993, the AS-PTA established a partnership with family farming organizations in two municipalities. To produce an overview of the local situation and guide its advisory work, it proposed the implementation of a participatory appraisal of agroecosystems to its local partners. Some years later, between 2001 and 2003, an updated survey of knowledge concerning the situation of family farming in the region was conducted, this time encompassing the social universe of 14 municipalities covered in the Pole's work. On this occasion, the territory was stratified into environmental zones by means of a participatory appraisal. Twenty-three years after the emergence of the agroecology network in the territory, a new update was carried out, this time seeking to focus more specifically on identifying the influence of public policies on the recent development trajectories in the family farming in the territory (all these activities included the participation of the authors and this paper presents partial results from the last update).

Although this second update considered the territory as a whole, a more in-depth analysis was undertaken in the municipalities covered by the environmental zone locally identified as Agreste do Roçado (Figure 1). As well as including a substantial portion of the farming families and organizations linked to the Pole, this portion of the territory is the setting for the development of sociotechnical networks that foment contrasting trajectories of agroecosystem intensification.

As an initial stage of the appraisal, a two-day seminar was held in the first half of 2015, attended by 60 family farming leaders, men and women, from the Agreste do Roçado region, with the objective of describing and analyzing the transformation to the family-based agroecosystems in the region. This analytic exercise, systemized in the form of a time line, enabled the group to discern the influence of public policies on the emergence and development of sociotechnical networks organized according to contrasting economic approaches. On one hand, networks were identified that drive intensification trajectories in line with the technical-economic paradigm of agricultural modernization. The tendency to generate a growing dependence of farming families on input and service markets was presented as a recurrent feature of these trajectories, which lead agroecosystems to different levels of technical-economic embedding in production chains of specific crops, such as potatoes, fennel, and tobacco in the past, and free-range chickens (caipirão) and intensive olericulture presently.

Figure 1. Environmental zoning of the Borborema Territory (Agreste do Roçado outlined in red)



On the other hand, the agroecology network dynamized by the organizations linked to the Pole drives production intensification trajectories that ensure the maintenance of high levels of autonomy of agroecosystems vis-à-vis the markets for factors of production (inputs, land, labor). This autonomy is also evinced by the fact that a considerable portion of the food consumed by farming families is produced by themselves. Furthermore, the gradual increase in the self-controlled resource base mobilized in the process of farm work was presented as a recurrent characteristic of these intensification trajectories guided by an agroecological approach.

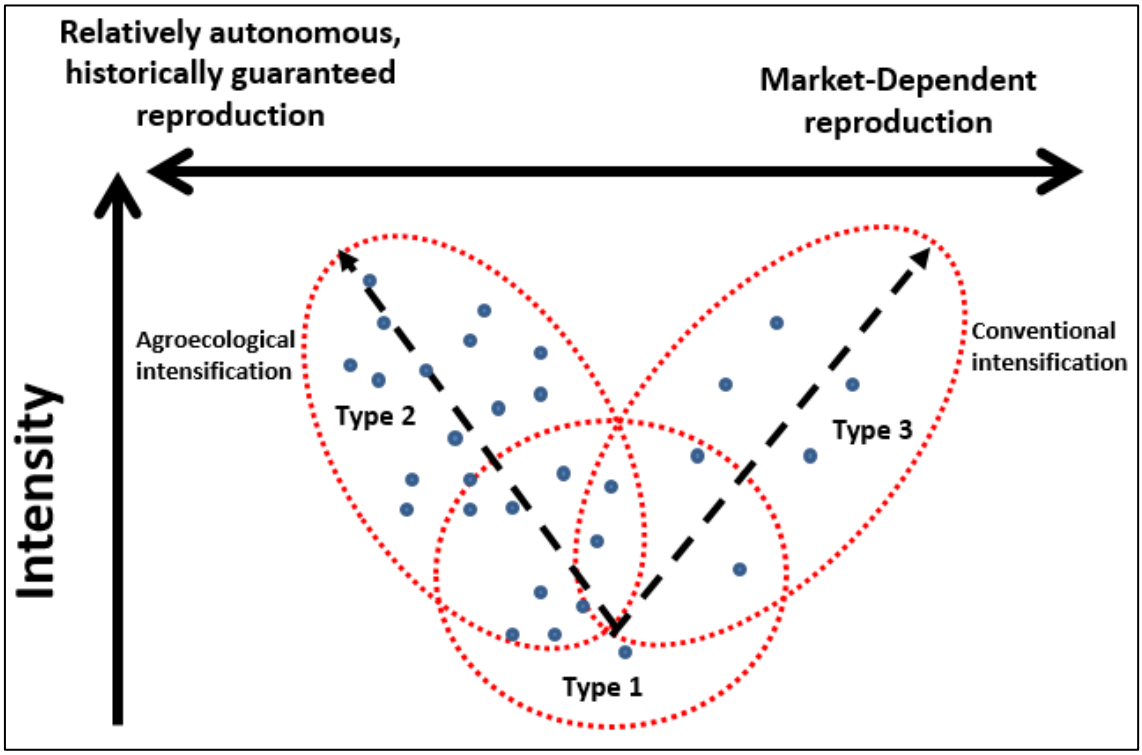
In the second stage of the diagnostic survey, semistructured interviews were held with 201 farming families.with the aim of characterizing in detail the evolving dynamics of family farming in the region and comparatively assessing the effects of different development trajectories on various criteria related to the technical-economic reproduction of agroecosystems.

The interviews used a script of open questions designed to identify transformations in the sociotechnical organization of agroecosystems, especially over the course of the last decade and a half, as well as various characteristics of their current configurations (a self-controlled resource base, the production of monetary and non-monetary and agricultural and non-agricultural income, relations with input and product markets, access to public policies, and so on).

Taking as a reference point the information obtained in the interviews, the agroecosystems were classified in three main categories: Type 1: traditional systems, i.e., those with a limited connection to sociotechnical innovation networks (87 interviews—43%); Type 2: systems linked to the agroecology sociotechnical network (102 interviews—51%); Type 3: systems linked to sociotechnical networks structured as specialized production chains (12 interviews—6%).

The diagram below schematically represents the transformations occurring in the region's agroecosystems over the recent decades (Figure 2). The two polar trajectories of agroecosystem intensification are illustrated by the dotted arrows. The trajectories linked to the agroecology network basically correspond to the processes of the transformation of Type 1 (traditional) agroecosystems into Type 2, i.e., those managed via *relatively autonomous and historically guaranteed* strategies of technical-economic reproduction (van der Ploeg 1993). As well as maintaining high levels of autonomy vis-à-vis input and service markets, other characteristics also detected in the Type 1 agroecosystems, these trajectories are distinguished by the gradual incorporation of technical and socio-organizational innovations that assure the continuous reproduction and enable the gradual quantitative and qualitative expansion of the self-controlled resource base mobilized in the labor process of farming families. In this sense, they typically comprise labor-driven intensification trajectories.

Figure 2. Contrasting intensification trajectories and resulting types of agroecosystems in Agreste do Roçado



The trajectories of technical-economic innovation linked to the specialized production chain correspond to the development of Type 3 agroecosystems whose reproduction strategy structurally depends on the mobilization of the factors of production in the markets. In this sense, they figure as conventional trajectories of production intensification (or capital-driven intensification).

One aspect to be emphasized in the model shown in the diagram is that the intensification trajectories illustrated by the dotted arrows correspond to an *ideal type*—in Max Weber's sense (Weber 2006)—of the development dynamics of family farming in the region. However, the interviews conducted with the farming families revealed a more complex empirical reality insofar as they showed the existence of various combinations between these patterns of technical-economic organization of agroecosystems. This means that, in many situations, the processes of innovation observed in the region's family farming establishments are guided by hybrid strategies that mix practices that are typical of two or more sociotechnical networks.

The outcome of the adoption of these multiple strategic possibilities in the organization of the labor process by the region's family farmers is the forming of a significant heterogeneity

among agroecosystems in terms of the levels of intensity and autonomy in relation to markets, or in other words, to the *degrees of commoditization* (Ploeg 1993) The degree of commoditization reflects the relative importance of market relations in the organization of the labor process in the agroecosystem. Analytically it corresponds to the ratio between the resources mobilized in the markets and those reproduced in the agroecosystem itself and/or mobilized in the community through relations of reciprocity. In the diagram, this heterogeneity is represented by the positioning of agroecosystems around these two main axes, forming three clusters that correspond to the predominant types of family farming.

According to the theoretical-methodological approach adopted to represent the diversity of family farming in the region, the agroecosystems may be located at the intersection of two or more clusters. This positioning that is *halfway* between two or more categories differs from the dualist classificatory schemas frequently adopted to represent the diversity of agriculture and to inform the design of public policies. The adoption of binary categories easily identifiable through simple and objective criteria, such as property size, income level, technical system adopted, and so on, tends to produce images of the agrarian world incongruent with the strategies of technical-economic reproduction adopted by family farming. The decision to pursue this perspective to representation, inspired by the farming styles approach proposed by Ploeg (1994), is founded on the understanding that agroecosystems correspond to the expression of technical-economic strategies adopted by farming families. Consequently they are not understood as sociotechnical configurations hermetically sealed in space or immutable in time, but as the sociomaterial outcome of the solutions actively constructed by farmers in response to the contexts of objective opportunities and constraints faced in the process of reproducing their means and ways of life.

2.3. Comparative Analysis of Contrasting Trajectories of Intensification

In order to comparatively assess the effects of contrasting development trajectories in family farming in the region, two typical cases were chosen from the universe of agroecosystems described above that express polar opposite situations. The first agroecosystem is strongly linked to the agroecology network dynamized by the Pole, while the trajectory of the second is linked to the sociotechnical network shaped by the production chain of free range chickens (caipirão) structured in the territory since the start of the 2000s. Both networks receive support from public funds, either for the implantation of infrastructures and processes of collective action (such as cooperatives, chicken processing units, projects for selling to institutional markets, etc.), or for financing and direct support for the farming families linked

to it. As well as expressing contrasting strategies for technical-economic reproduction, the two agroecosystems were selected since they possess similar sized territories (around 15 hectares) and equivalent workforces (2 Family Labor Units).

In order to identify the contributions made by both the agroecosystems and the sociotechnical networks to which they are connected toward rural development, an economic-ecological method of agroecosystem analysis was employed. The method was proposed by AS-PTA with the aim of highlighting the economic, ecological, and political relations that set apart the modes of production and ways of life of family farming, but which have been systematically eclipsed or distorted by conventional economic theory (Petersen et al. 2017).

To carry out the present study, the method was put into practice in two subsequent stages. In the first phase, semistructured interviews were conducted with the families in order to collect the information needed to describe and analyze the evolving trajectories of the agroecosystems and to develop representative models of the structure and economic-ecological functioning of the agroecosystems in the year of the study (2015). The information on the trajectories taken by the agroecosystems was systemized in the form of time lines, which allowed mapping of the significant changes inside and outside of the farms. This methodological approach made it possible to identify the logics involved in mobilizing the recourses of public policies aimed at farming families in order to promote the structural and functional transformations in agroecosystems. The models, elaborated in the form of flow diagrams, are schematic representations that enable the identification of the circulation of inputs and products, monetary and non-monetary incomes, and the social division of labor between family members and between the family and outside economic agents.

In the second phase, through a new interview, the economic-ecological flows represented in the models were quantified and the data obtained was fed into an electronic spreadsheet specifically designed to generate a wide-ranging set of economic indicators. The comparative analyses are quali-quantitative in nature and are grounded in the information and data collected via in-depth interviews with the families managing the two agroecosystems.

3. Results

3.1. A Trajectory of Agroecological Intensification

The family of Paulo and Josefa resides in the Oziel Pereira rural settlement in the municipality of Remígio (PB). For 21 years, since their marriage in 1978, they have been a landless family. The couple obtained income by working the land owned by other people, either as tenant farmers, or as sharecroppers, or with the right to plant fields for a two-year period in exchange for clearing land for pasture. One of the areas where Paulo worked in the past was precisely where the family was settled, in 1999, after years of activism in the Landless Rural Workers Movement (MST). When they took possession of their plot of land, Paulo and Josefa discovered they had been given a heavily degraded area, "completely treeless", a situation reverted over the years through organic fertilization of the soil and reforesting of the area with multifunctional tree species.

Through their participation in the community association, the family became an active member of the agroecology sociotechnical network dynamized by the Pole with the local Rural Workers Union functioning as a channel of dialogue between the community and territorial spheres. It is also worth emphasizing the Pole's integration in sociotechnical networks organized at higher geographical levels, such as the Paraíba Semi-Arid Alliance (ASA-PB), the Brazilian Semi-Arid Alliance (ASA), and the National Agroecology Alliance (ANA). Based on this multilevel social participation, the agroecosystem's development was heavily shaped by the processes of learning and experimentation generated in the networks of farmer-experimenters assisted by the Pole and AS-PTA, as well as by the political capacity of the Pole and its organizations in mobilizing and channeling public resources to enable transformations in the territory in line with the agroecological approach.

In addition to the already mentioned reforestation of the lot, favored by the existence of a territorial network of community nurseries, over the years the family incorporated a set of management practices closely connected to processes organized by the Pole. Among them, we can highlight: the use of adapted seeds, seasonally-timed access that is ensured through participation in the community seed bank and in trials of local maize varieties organized by the Paraíba Semi-Arid Alliance (ASA-PB) in partnership with the Brazilian Agricultural Research Corporation (EMBRAPA); implantation of cisterns for collecting rainwater for human consumption and for production with resources obtained from public programs implemented by the Brazilian Semi-Arid Alliance (ASA); restructuring and intensifying house yard production

with resources mobilized in a community revolving fund; an increase in the volume of forage produced and stored, making use of a forage machine managed by the Remígio Rural Workers Union and obtained through the Citizenship Territories program from the Agrarian Development Ministry; participation in the municipal agroecological fair and the sale of produce to the National School Meals Program (Programa Nacional de Alimentação Escolar: PNAE).

The gradual incorporation of technical and organizational innovations in the agroecosystem, made possible by material investments associated with learning processes and local experimentation, helped broaden the family's self-controlled resource base and simultaneously enhance the process of converting these resources into a diverse range of products for market sale and self-consumption. As well as the access to land through the land reform program, the family was able to combine the resources mobilized through different public policies—including income transfer programs—to build a multiproduct unit with low technological dependence, which provides them with a high level of food security and enables them to sell their produce via diverse local markets. The changes introduced to the family's house yard under Josefa's leadership assumed a prominent role in the reorganization of their work and in the economic results of the agroecosystem as a whole (an aspect to be examined later).

3.2. Effects on Rural Development

The trajectory through which the agroecosystem run by Paulo and Josefa's family became constituted cannot be assumed to be a generalizable empirical expression of the agroecosystems connected to the Agroecology network in the territory. A complex set of material and immaterial factors, both internal and external to the rural establishments, influence the strategic decisions taken by families and, consequently, the development trajectories taken by agroecosystems. Ultimately, each agroecosystem then possesses a unique configuration that expresses the contingent result of the accumulation of strategic decisions taken over the years. However the analyses undertaken through concrete reference to this agroecosystem are valid in terms of extrapolating the potential effects at the territorial level, allowing the identification of a variety of contributions to the agroecosystems linked to the agroecology sociotechnical network for rural development.

From the environmental viewpoint, the style of economic management of the agroecosystem contributed simultaneously to: (a) a continual renewal of the fertility of the cultivated lands

through intensive production cycles and the restoration of biomass to the soil, a significant aspect in a region subject to processes of desertification (contributing to the reach of SDG 15); (b) the conservation and enrichment of agrobiodiversity, based on the adoption of a diverse set of valued practices linked to economic and ecological functions of the local genetic resources—i.e., local plant varieties and native livestock breeds, replanting with species with multiple purposes, etc. (SDG 15); (c) completely dispensing with the employment of pesticides and other contaminating inputs (SDG 3 and 12).

When considered together with the diverse range of economic options available to the family, these environmental management practices confer greater resilience to the agroecosystem, a fact verified in the most recent period of sustained drought, which has already lasted for five years. Furthermore, this pattern of managing the farm landscape, based on geobiochemical cycles propelled by photosynthesis, contributes to a reduction in the levels of greenhouse gas emissions (SDG 13). These results demonstrate the possibility of reconciling practices of agricultural intensification and strategies for mitigating and adapting to climate changes. In other words, it means that the challenge of intensifying farming does not necessarily imply the appropriation of natural assets through predatory practices. On the contrary, the experience reveals the possibility of attaining the objectives of intensifying farm production while restoring degraded landscapes (SDG 8).

These processes of protecting and expanding ecological capital at the levels of the agroecosystem and the territory cannot be comprehended separately from a strengthening of social capital—that is, the improvement of the collective action mechanisms used to build, defend, and continuously replenish common goods. To boost these processes, the Pole and AS-PTA have fostered an intense social dynamic aimed at producing and sharing knowledge and involving activities related to participatory appraisals, local experimentation, exchange, and research in partnership with official scientific-academic institutions. As a common good, knowledge circulates freely in the sociotechnical network, helping boost human capital and, consequently, the quality and efficiency of labor (SDG 4).

Still on the question of the expansion in social capital, it needs to be emphasized that the creation and strengthening of tools for managing common goods in the region's communities occur in association with a deliberate strategy of the Pole and AS-PTA to overcome the patriarchal culture and the various forms of violence against women, creating better

environments for critical reflection on gender inequalities. These in turn helped foment a regional movement in support of the political and economic emancipation of women in private and public spaces (SDG 5). In Josefa's case, for example, her active involvement in community revolving funds allowed her to obtain wire mesh to fence off her yard and animals in order to expand and improve the quality of her poultry livestock. Furthermore, Josefa's integration in this community-level space facilitated her entry into the women's movement at the territorial level, participating in various exchange visits and six annual editions of the Women's March for Life and Agroecology, co-organized by the Pole and AS-PTA.

The horizontal spread of the network through the region's municipalities, engaging an ever increasing number of family farmers, is anchored in and contributes to the strengthening of territorially rooted institutions based on relations of reciprocity (SDG 16). The creation of 65 community seed banks and eight community nurseries, the setting up of 140 community revolving funds, the collective management of twenty motorized silage machines for processing and storing forage, the swapping of knowledge and genetic material in exchange activities, as well as the various forms of cooperative work (work rallies, day swaps, local fairs), are more or less formalized expressions of the strengthening of institutional capital, a decisive condition for individual capacities to be mobilized in support of actions of the collective interest without the need for the intermediation of commodified relations.

One important practical implication of the amplification and management of common goods for rural development is the increase in the quality of the labor processes and products in agroecosystems. Among the various expressions of this improvement, we can highlight the quality of the food produce, whether destined for self-consumption or for market sale. Given the rise in health issues associated with the consumption of processed foods and/or with residues of pesticides and other contaminants, this is undoubtedly an especially important positive effect (SDG 3 and 12).

The creation of the Borborema Territory Association of Agroecological Farmers (Ecoborborema) in April 2005, set up to stimulate the commercial outlet for diversified and differentiated food production, was one of the key moments in the evolution and densification of the network run by the Pole. Responsible for coordinating a set of 12 agroecological fairs and managing projects for the sale of produce in institutional markets, Ecoborborema has played an essential role in broadening and diversifying the actors belonging to the

sociotechnical network, especially by establishing connections with growing portions of the urban population in the region's municipalities. This valorization of local production in ever broader social circles within the territory is a key element in strengthening its symbolic capital, i.e., in the increased public recognition of the benefits generated by the family farming mode of production linked to the Pole.

3.3. Impacts on Family Economies

As well as helping to strengthen the agroecology sociotechnical network, the public policies for family farming implemented in the territory over recent decades have supported the development of production chains for specific food produce such as potatoes and tobacco in the past, and free range chickens (caipirão) and intensive vegetable cultivation in the present. The logic of economic intensification of agroecosystems linked to these chains tends to generate processes of ecological simplification and increased dependence on commercial inputs. At the same time, the higher level of productive specialization makes these agroecosystems more dependent on commercial relations over which the families themselves have little or no control.

Contradicting the central argument propagated by advocates of agricultural modernization, comparative economic analyses conducted in the region have systematically demonstrated that increases in the value of the production of the agroecosystems linked to these chains do not necessarily yield agricultural incomes any higher than those obtained by families who do not make use of modern technologies.

This fact became apparent when the economic yield of the agroecosystem managed by Paulo and Josefa was contrasted with an agroecosystem of analogous size (around 15 hectares) and labor capacity (two adults), but which followed a conventional intensification trajectory, today managed with the intensive use of external inputs following an economic logic based on intensive capital inputs. In this case, the agroecosystem employed as a comparative reference, identified here as AE1, is linked to the productive chain of free range chickens, a sociotechnical network that first emerged in the region at the start of the 2000s. This network is strongly polarized by a regional cooperative of poultry breeders and has been able to mobilize resources from public policies for credit, material support, and rural extension services. The free range system of poultry breeding has been actively promoted as a labor and income alternative for the region's family farmers, including the mobilization of resources from social policies like the Misery-Free Brazil Program (Programa Brasil Sem Miséria), an initiative

launched by the Brazilian government in 2011, with the objective of drastically reducing the poverty indices in the country through the social and productive inclusion of the section of the population considered to be living in extreme poverty. However, the logic of technical-economic management of the activity leads families to establish ties of structural dependence with the input and service markets (purchase of feed, chicks, and other production inputs, hiring outside labor).

In technical terms, while the AE1 management style follows the logic of an economy of scale, seeking to reduce unit costs through specialization and through the continual increase in the operational dimension of the production processes, the agroecosystem run by Paulo and Josefa's family, AE2, is based on the logic of an economy of scope, seeking to reduce total costs through a synergy between the productive activities. Specialization and scale, on one hand, diversity and synergy, on the other, are keywords for defining what distinguishes the two management styles.

An eloquent numerical expression of this contrast is given by the diversity of items produced in the two agroecosystems. While AE1 produces two items in two subsystems (poultry and cattle), AE2 produces 23 items in 4 subsystems (crops, fruits, cattle, and poultry). Through a complex of synergistic relations between the different activities performed, AE2 comprises a dense web of economic-ecological flows strategically organized in space and time to attain an integrated set of family objectives.

When we turn to consider monetary and non-monetary economic flows, the comparative analysis of the annual economic yields of the two agroecosystems reveals aspects usually hidden in conventional accounting, though they are central to understanding the economic operation of family farming. Focusing narrowly on Gross Value of Production (GVP), the main economic indicator used in official agricultural statistics, AE1 presents an annual performance 2.6 times higher than AE2 (R$107,500 versus R$40,200). However, when our focus of comparison shifts to the clean part (net yield) of economic production—the agricultural income—a superior performance of AE2 is observed (R$26,000 versus R$31,700).

A panorama even more divergent from conventional economic approaches is revealed when we turn our comparative analysis to land productivity. Observing that the two agroecosystems generate similar agricultural incomes per hectare (R$1547 versus R$1717), a conventional analysis would conclude that they possess an equal level of efficiency in terms of allocating this

factor of production. However, when we analyze the situation from the viewpoint of the ecological economy, it becomes clear how many virtual hectares are needed for the production/extraction of the resources obtained from the markets—with costs reaching R$73,000—to activate the productive processes of AE1. This means that the labor process in the management of AE1 consumes resources appropriated in a much larger environmental space than the space directly exploited by the agroecosystem (principally the inputs for making feed, produced in large transgenic monocrop plantations in the Cerrado region of Brazil), revealing a low level of endogeneity of AE1 (0.29) compared to AE2 (0.79), whose production costs (intermediary consumption) were just R$8000 (obs.: A representation of the endogeneity of the agroecosystem through a synthetic index is obtained through the ratio between Added Value and Gross Income). Applying these indices to the adjustment of the land productivity indicators, we can conclude that AE2 is 302% more intensive than AE1 (R$448/ha versus R$1356/ha). In this analysis it should be noted that AE1's main income generating activity, poultry breeding, makes virtually no use of the ecological resources provided by the agroecosystem itself. Hence conventional analyses tend to generate a somewhat distorted picture of the degree of technical efficiency of modernized establishments insofar as the income generated by them does not effectively express the technical efficiency in the use of local environmental resources.

This analysis of land productivity through non-conventional lenses reveals the essential difference between the logics of intensification adopted by the two families. While the management of AE1 is associated with an intensive and constant application of capital, AE2, run by Paulo and Josefa's family, makes use of most of the factors of production from a self-controlled resources base, built up slowly over the years and continually regenerated by investing the labor of the family itself, including towards the maintenance and expansion of relations of reciprocity established at the territorial level.

4. Discussion

Although the two agroecosystems taken here as benchmarks do not represent the significant heterogeneity of family farming in the Borborema Territory, the analyses derived from them enable a number of comments to be elaborated on concerning the effects of public policies on rural development dynamics. This is because they illustrate two practically opposite trajectories of agricultural intensification. Between these two polar situations, the reality on the ground contains a varied mixture of technical-economic management rationales. In this

sense, the resulting heterogeneity of agroecosystems may be interpreted as the expression of hybrid strategies that combine investment in labor and capital in different proportions.

It is important to stress that the strategies adopted by the families reflect legitimate options for continuing to reproduce themselves as family farmers in response to the structural conditions encountered by them in the territory. Hence the focus of analysis should be on the institutional environment in which these decisions are taken in the private sphere, in particular on the influence of State action on the creation of the conditions for developing and consolidating the multifunctional potential of family farming, including those sectors historically considered marginal, peripheral, or non-viable.

Firstly, we need to focus on the role of the State in working to resolve a decisive factor in the political economy of agriculture, namely the agrarian question. The experience of Paulo and Josefa's family is emblematic of the relevance of land reform to compliance with the constitutional provisions related to the social and environmental functions of the land. In little more than a decade, the settled family and community have transformed the landscape from a large economically unproductive and environmentally predatory farm into a space generating hundreds of decent jobs and steady sources of income to meet their economic needs, by diversifying the production of the agroecosystems. It is worth emphasizing that Paulo and Josefa's children also obtained plots of land through the land reform program, demonstrating the role of this policy in the intergenerational reproduction of family farming. In addition to the direct benefits for settled families, and in an effective contribution to the structural overcoming of poverty (SDG 1) and food insecurity (SDG 2), this State intervention was decisive in terms of stimulating the territorial economy (SGD 8), the ecological restoration of degraded areas, and the increase in the production of quality food produce to supply local and regional markets (SDG 12).

The family's experience also emphasizes that, beside land redistribution, other public initiatives are essential for making space for the expression of the multifunctional potentialities of family farming. The resources redistributed by different public policies where channeled by the family towards strengthening typically peasant strategies of economic reproduction, i.e., driving trajectories of intensification rooted in the management and continual expansion of the self-controlled resource base (van der Ploeg 2008).

The presence of a social environment favorable to the production of contextual knowledge and the generation of local innovations proved to be an indispensable condition for self-controlled endogenous resources to be identified, valorized, and amplified. Here we can stress the decisive role played by AS-PTA's advice in the use of an agroecological perspective to comprehend the socioenvironmental peculiarities of the territory and the agroecosystems operating within it. This perspective is directly opposed to the focus on technological diffusionism that has historically influenced the organization of the extension service and agricultural research institutions.

The public programs for implanting decentralized infrastructures for catching and storing rainwater (P1MC and P1 + 2) have performed an essential role in this trajectory by functioning as the triggers of processes of sociotechnical innovation, contributing to the reorganization of the labor processes in the agroecosystems and rural communities. On one hand, they helped to substantially reduce the time dedicated to obtaining water for human consumption, generating a series of positive effects for families, particularly for those individuals previously involved in this activity, traditionally women and children. Here we can also highlight the significant improvement in the quality of the water consumed with positive impacts on collective health (SDG 6). On the other hand, they enabled an increase in the water reserves directed towards production, contributing to a rise in the efficiency of land use and labor.

The intensification in house yard production, with substantial impacts on the income generation and food security of local families (SDG 2), was one of the most significant outcomes of the installation of water infrastructures. The relative economic importance of these spaces is illustrated by the agroecosystem managed by Paulo and Josefa. Despite occupying just 0.5% of the agroecosystem's total area, the house yard, a space primarily managed by Josefa, was responsible for generating 24% of the family's agricultural income in the year when the study was conducted, a drought year. Another notable effect of the programs is the greater stabilization of livestock herds and flocks during the dry periods of the year, another hugely important contribution to the resilience of the agroecosystems.

However the innovations brought about by these programs are not limited to the technical dimension. Both programs were conceived and successfully introduced by ASA after lengthy negotiations with a series of federal government administrations. Along with obtaining the funds needed to implement the infrastructures, ASA negotiated an innovative mode of

partnership with the State that enabled joint execution and public oversight of the programs. Through this innovative framework, the Borborema Pole, along with hundreds of other organizations linked to ASA, was able to optimize its role as a collective actor in the promotion of territorial development dynamics. By strengthening the capacities of civil society organizations to execute and oversee the use of public resources, the partnership between governmental and non-governmental public entities has helped shift beyond a political culture congenitally linked to clientelist practices responsible for reproducing the political and economic subordination of the most impoverished sectors of the rural population within oligarchical local power structures.

Instead of submitting the most vulnerable farming families to clientelist relations and those able to make a modest living through dependency on the agribusiness sector, this style of joint public policy management has helped to strengthen political citizenship and to activate and dynamize social mechanisms of reciprocity, amplifying social capital in the territory, a decisive element in terms of the generation of common goods managed by the organizations and families linked to the Pole.

The development of a variety of collective action devices in the territory has also depended on the crucial support of resources redistributed by government policies. Among these we can highlight the short circuits to commercialization (institutional markets and agroecological fairs), community seed banks and nurseries, solidary revolving funds, machinery for making screens and fencing, and the silage machines for collective use. These and other initiatives created and consolidated through the sociotechnical network coordinated by the Pole are important expressions of rural development dynamics unleashed through the coproduction of public action involving the State and territorially-based civil society organizations. They also express the capacity of territorial-level sociotechnical networks to mobilize and provide coherence to public resources derived from different government policies, including those not directly identified with rural development.

Here we can emphasize the pronounced influence on the trajectory of the network exerted by income transfer policies, especially rural pensions and the Family Allowance Program (Programa Bolsa Família), a federal government direct income transfer program, targeted at families living in poverty and extreme poverty in rural and urban areas. Firstly, regular access to these resources among the most impoverished families (rural and urban) has contributed to

an increase in the overall demand for food produce. In this sense, income transfer policies perform polyvalent functions in the territory, not only by reducing levels of poverty and food insecurity but also by dynamizing the regional economy through the valorization of the work of family farming. Moreover, it should also be observed that access to these resources by farming families significantly expands the margins of freedom for them to improve their economic reproduction strategies, not only by responding to more pressing needs, but also by assuring the regular influx of financial resources that are partly invested in structural improvements to the agroecosystems. This aspect is particularly important for women farmers, since their direct access to financial resources comprises a powerful tool of emancipation from the double condition of subalternity to which they have traditionally been submitted: by being poor in a structurally unequal society; and by being women in a culturally patriarchal society. Hence, whenever this is combined with multiple strategies for economic and political emancipation, the income transfers effected by social policies generate multiplying effects on territorial development.

Although the higher rates of decline in extreme poverty in Brazil over recent years have occurred precisely in the semi-arid region (Araújo 2014), revealing the universal effect of income transfer policies, they do not necessarily imply the inauguration of development trajectories capable of overcoming the structural conditions responsible for the pronounced social inequality experienced in the region. The effects of these social policies on the improvement of the welfare conditions of the poorest families and, in some cases, on the stimulation of local markets are not enough by themselves to transform the productive bases of the rural territories since their resources are primarily used to purchase essential goods not produced locally (a substantial portion of food items, medicines, clothing, household appliances, furniture, building materials, and school materials) (Favareto 2015). On the other hand, the experience of the most socially vulnerable family farmers linked to the sociotechnical network coordinated by the Pole demonstrates that the alleviation of severe hardship through regular access to social policy resources comprises an essential condition for them to obtain enough room for maneuvering to be able to join trajectories of material accumulation based on labor-driven intensification processes.

The substantial improvement in the public service provision in the areas of education, health, and infrastructure (rural power supply, communications, road systems, etc.) in the territory have also contributed to expanding the freedom of the poorest farming families to invest their

labor in self-emancipation processes. As the Indian economist Amartya Sen (2000: 66) made clear: “The quality of life can be vastly raised, despite low incomes, through an adequate program of social services”. This observation led the author to challenge the idea of trickle-down economics used to justify keeping large swathes of the population in poverty as a necessary sacrifice for national economies to grow and create the structural conditions for ‘sharing the cake’ later.

The empirical evidence observed in the Borborema Territory over recent decades corroborate this challenge to orthodoxy by the winner of the Nobel Prize for Economics. The Agroecology sociotechnical network coordinated by the Pole combined resources endogenous to the territory with resources redistributed by the State to drive a robust dynamic led by regionally interconnected collective actors working to build and defend their own project for rural development amid a social universe conventionally labelled marginal and unproductive. This dynamic unfolded through autonomous strategies of economic reproduction based on processes of coproduction with nature, on the expansion of the practices of reciprocity in the management of common goods, and on the local production of technical and organizational innovations. The process thus promotes the creation of a new political and institutional culture that gives a new meaning to public action, contributing to the decentralization of State action and to strengthening the ties between the dynamics of territorial development and the deepening of participatory democracy.

5. Conclusions

In adequate political-institutional conditions, the most impoverished portions of family farming can become the leading agents of rural development dynamics, contributing to the combined attainment of various SDGs. In this sense, the evidence presented here directly contradicts influential arguments that downplay the economic vocation and innovative capacities of this largest section of the rural population. These conditions should favor the emergence and development of territorially-based sociotechnical networks capable of mobilizing and synergically combining public resources redistributed by the State and endogenous social-material resources.

The agroecological paradigm offers the conceptual grounding and adequate methodological tools for the identification, recombination, and continuous improvement of the resource base self-controlled by rural families and communities in order for it to be valorized in productive intensification trajectories. From this viewpoint of sociotechnical innovation alone, the

trajectories of productive intensification can be considered sustainable since they do not place demands on the systematic importation of material and energy. However, in order for the agroecological intensification approach to be put into practice at ever wider social and geographic levels, it becomes necessary to strengthen the institutions of participatory democracy in order for public policies to be continuously improved, allowing critical and active citizenship to exert a leading role in the governance of agri-food systems.

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4 – Conclusiones

El conjunto de trabajos que conforma esta tesis doctoral está articulado en torno a indagaciones relacionadas al desafío de la "ampliación de la escala" de la agroecología como enfoque para la reestructuración de los sistemas agroalimentarios desde del ámbito local hasta el global. Por variadas perspectivas de análisis, los trabajos reflejan sobre las mediaciones institucionales involucradas en la aplicación de ese enfoque como abordaje para la transformación del metabolismo de los agroecosistemas y, de forma correspondiente, de las relaciones sociales, económicas, políticas y ecológicas establecidas en el ámbito del sistema agroalimentario.

Siendo un paradigma científico que emergió en las ciencias agrarias, la agroecología mantiene su foco de atención privilegiado en la análisis y planificación de la transición socio-técnica de los agroecosistemas, asumidos aquí como unidades de gestión técnico-económica en la agricultura. Aunque sea notoria la diseminación global de la agroecología en esta escala micro, es también cierto que ha sido limitada la irradiación de estas fructíferas iniciativas pioneras en los mismos territorios donde las mismas surgen. Esta restrita diseminación horizontal indica que el aumento de escala de la aplicación de la perspectiva agroecológica no se procesará espontáneamente, a partir de la capacidad demostrativa de las experiencias exitosas, aunque ellas presenten respuestas consistentes para el enfrentamiento conjugado de varios desafíos relacionados a la crisis de civilización contemporánea (Toledo 2012; Garrido Peña et al. 2007).

Esta constatación trae la dimensión política al centro del debate sobre transición agroecológica en escalas mas agregadas (González de Molina 2013) ya que los cambios en este nivel encierran profundos desafíos relacionados con la necesidad de nuevos arreglos institucionales capaces de alimentar y dar sustento a una "cultura de la sustentabilidad" (Gliessman et al. 2007).

Como sugerí en esta tesis, la Agroecología Política comprende la agroecología como una construcción social movida por las convergencias y disputas entre agentes económicos y sociopolíticos en espacios territoriales definidos. En ese sentido, debe dedicarse al estudio de las relaciones de poder implicadas en las esferas de producción, transformación y circulación de valores, así como la distribución social de la riqueza generada por el trabajo agrícola.

La complejidad involucrada en las relaciones que se establecen entre actores, artefactos, reglas e instituciones en las dinámicas de cambio sociotécnico de los sistemas agroalimentarios, indica que la "ampliación de la escala" de la agroecología no ocurrirá como un proceso lineal basado en transferencia de tecnologías y conocimientos, en sintonía paradigmática con la teoría de la modernización agrícola. Como señala Scott (2008: 271) "la creencia en la posibilidad de universalización y difusión de un sistema codificado de conocimientos y artefactos para los más distintos ambientes ecológicos y socioculturales son parte integrante de los modos de organización de la agricultura y del espacio rural hoy hegemónicos".

La internalización del paradigma agroecológico en las instituciones que regulan el metabolismo de los sistemas agroalimentarios supone no sólo el cambio en la concepción técnico-económica de gestión de los agroecosistemas, sino también la propia gramática del proceso de

transformación del régimen socio-técnico dominante. En este sentido, parece poco adecuado el empleo del concepto de "revolución agroecológica" para la descripción y análisis de procesos de diseminación de la práctica agroecológica verificados en países (Sosa et al. 2008) o mismo en el ámbito de un continente (Altieri e Toledo 2011).

Los estudios presentados en esta tesis enfatizan la importancia crucial que asumen los complejos y muchas veces contradictorios procesos sociales en territorios rurales como arenas de disputa donde interaccionan el medio natural, las familias agricultoras y sus organizaciones y los demás agentes económicos y políticos que participan o cuyas acciones también interfieren en la gestión de las dinámicas de desarrollo rural.

El énfasis atribuido por la Agroecología Política al territorio rural como locus privilegiado del desarrollo rural, apunta a una nueva perspectiva geopolítica y geoeconómica para el diseño de arreglos institucionales adecuados al aumento da escala. Entre otros aspectos implica la descentralización de las instituciones (incluso los mercados) que regulan el metabolismo agrario con la redistribución del poder para que sean creadas condiciones efectivas para la activa participación de la población en la planificación y gestión de los procesos de producción, distribución y consumo de alimentos.

La afirmación de la centralidad del territorio como centro gravitacional de las dinámicas de desarrollo rural basadas en el paradigma agroecológico no significa que la Agroecología Política no se ocupe de estudiar y orientar la intervención sobre el diseño institucional en escalas superiores, es decir, en los ámbitos nacionales y supranacionales a partir de los cuales, cada vez más, los destinos de la agricultura y de la alimentación vienen siendo planificados y controlados por estructuras de poder que se conforman como “imperios agroalimentarios” (Ploeg 2009).

Como se demostró en los estudios aquí presentados, referidos a la realidad de Brasil, las políticas gubernamentales pueden ejercer un papel determinante en el fortalecimiento de iniciativas social y ecológicamente contextualizadas de promoción de la agroecología. Al contrario del sesgo externalista y estructuralista que orienta el diseño de las políticas de modernización agrícola, en los casos empíricos estudiados los recursos públicos redistribuidos por el Estado fueran sinérgicamente combinados con recursos endógenos, ya sean materiales o inmateriales, favoreciendo el despliegue de trayectorias de innovación socio-técnica protagonizadas por los actores del territorio articulados en redes.

Además de apoyar procesos de transformación de las prácticas de gestión técnico-económica en el ámbito de los agroecosistemas, una nueva generación de políticas públicas para la agricultura familiar en Brasil (Grisa e Schneider 2015) fue determinante en el fortalecimiento de arreglos institucionales territorialmente referenciados, no sólo redistribuyendo recursos financieros, sino también el propio poder de gobernanza sobre las dinámicas de desarrollo rural.

La escala territorial permanece como una esfera de intervención hasta entonces poco privilegiada por las organizaciones académicas y movimientos sociales que integran el campo agroecológico. Sus focos de atención transitan entre la escala micro, representada por las unidades de producción (los agroecosistemas), y la esfera macro, representada por las

superestructuras políticas e institucionales formadas por los Estados y por los espacios de gobernanza multilateral en el ámbito internacional. El territorio rural se sitúa entre una esfera y otra, presentándose por esto como una arena sociopolítica intermediaria para la agregación de fuerzas sociales en defensa de la soberanía alimentaria, la justicia ambiental y social, la salud colectiva, la sustentabilidad y, en la mediación de todos estos objetivos fines, la democracia participativa.

El método de análisis económico-ecológica de agroecosistemas descrito en esta tesis se presenta como un potencial instrumento de la Agroecología Política exactamente por orientar procesos colectivos de construcción de conocimientos sobre las dinámicas de desarrollo territorial. Entre otras aspectos positivos él proporciona:

1 – Resituar el desarrollo rural como una dinámica socialmente construida en el tiempo y en el espacio, rompiendo con el sesgo determinista y alienante impuesto por el paradigma de la modernización agrícola;

2 – Concebir el desarrollo rural como una construcción social realizada a partir del protagonismo de las familias agricultoras, sus organizaciones locales y otros agentes del territorio cuyas acciones e intereses influencian el diseño de los sistemas agroalimentarios locales;

3 – Concebir el agroecosistema como un sistema socioecológico, cuyas trayectorias de desarrollo son determinadas por las estrategias de reproducción social y económica de las familias agricultoras elaboradas y puestas en práctica como respuestas activamente construidas a las transformaciones en los ambientes institucionales en los territorios rurales;

4 – Identificar y analizar trayectorias de desarrollo de agroecosistemas que se desvían de los caminos propugnados por la modernización agrícola;

5 – Contrastar distintas estrategias de desarrollo de agroecosistemas en un mismo territorio rural, evidenciando diferencias en la distribución de las riquezas generadas por el trabajo entre las familias agricultoras y los agentes del agronegocio y los diferentes niveles de sustentabilidad ecológica.

6 – Dar visibilidad a las prácticas no mercantiles de gestión de los agroecosistemas y su importancia para el desarrollo rural;

7 – Conferir mayor consistencia conceptual y metodológica a la promoción de dinámicas de transición agroecológica, evidenciando la importancia estratégica de la valoración de los recursos endógenos en la dinamización y en la sustentabilidad de las economías rurales;

8 – Proporcionar subsidios de información técnica, económica y socio-política para el fortalecimiento de las redes socio-técnicas de agroecología;

9 – Dotar a las organizaciones de investigación agrícola y extrensión agraria de instrumentos para la evaluación de la realidad agraria coherente con el paradigma de la agroecología.

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